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THIS JOURNAL IS DEVOTED TO THE SCIENCE AND TECHNOLOGY OF PAINT APPLICATION, ELECTRODEPOSITION, VITREOUS ENAMELLING, GALVANIZING, ANODIZING, METAL SPRAYING & ALL METAL FINISHING PROCESSES. THE EDITOR IS PREPARED TO CONSIDER FOR PUBLICATION ANY ARTICLE COMING WITHIN THE PURVIEW OF "METAL FINISHING JOURNAL" AND ALL SUCH ARTICLES ACCEPTED WILL BE PAID FOR AT THE USUAL RATES.

Contents

PAGE

Atomic Influence **295**

Talking Points **296**
" Platelayer "

Some Considerations in Relation to the Hot-Dip Galvanizing of Guard Rails **297**
H. Bablik, F. Gotzl and E. Nell.

Finishing Post **300**

Institute of Metal Finishing : Annual Conference Report (*cont.*) **301**

Enamelling News Letter from Finland **304**

Electropolishing and Related Techniques **305**
A. A. Tomkins

Properties and Applications of Flame Sprayed Refractory Coatings **313**
Lloyd Manuel

Finishing News Review **317**

Plant Processes and Equipment **325**

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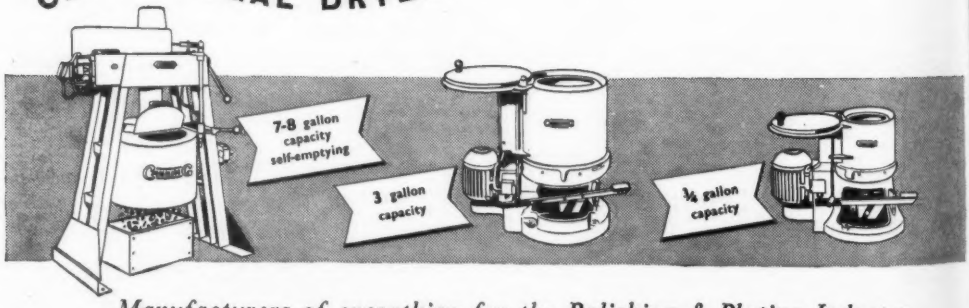

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TOMIC INFLUENCE

THE present industrial preoccupation with the atomic nucleus as a source of energy tends to overshadow the significance of the role played by the atom itself as the ultimate elemental particle. Undoubtedly a knowledge of the construction and behaviour of the atomic nucleus and its orbital electrons must contribute to a proper understanding of atomic behaviour, but much of to-day's industrial research is concerned more with the activities of atoms and molecular groupings than with sub-atomic particles. For example, any fundamental study of the mechanism whereby an electrodeposited coating is initiated and built up must concern itself largely with the behaviour of metals at the atomic level.

The first work to be undertaken along these lines in this country is currently being carried out in the Department of Industrial Metallurgy at the University of Birmingham, and two progress reports on findings so far have been made by Dr. H. J. Pick in the form of papers to the Annual Conference of the Institute of Metal Finishing. A particularly interesting feature of this work has been that by the development of ingenious techniques it has been possible to produce a cine film record at very high magnification of the initiation and growth of a copper electrodeposit. The use of single crystal and polycrystalline cathodes as a basis for deposition has also made possible observations on the effect of the crystallographic orientation of the cathode surface on the resultant crystal structure of the electrodeposit.

Metallurgical science has made available a large body of knowledge on the physical properties of metals and alloys and on ways of modifying these properties, by heat treatment and various forms of working, so as to suit them for particular applications. These modifications and properties are brought about by alterations in the microstructure of the metals, and progress is being made in correlating structure with performance. An electrodeposited coating is subject to the same criteria as are metals in more massive form, although the formation of the metallic layer is brought about in a highly specialized manner. Nevertheless, the growth of the crystalline metallic structure during the course of electrodeposition can be considered to have many features in common with the growth of crystal structures during the course of solidification from a melt or sublimation from the vapour phase. The ability to study, and still more to record this process on an atomic or at least a molecular scale, must inevitably prove to be a most valuable weapon in the onslaught on the realms of ignorance which still exist in the correlation of plating practice and coating performance.

It is certainly not difficult to envisage the advantages which would obtain from being able to produce an electrodeposited coating with a tailormade specification with regard to its chemical and physical properties by the modification in a known manner of the variables in the plating process. The fact that such properties as hardness and brightness of coatings are already to a considerable extent under control, although the mechanism of control may be imperfectly understood, is a forerunner of what it may be possible to do in the future as a result of research at the atomic level.

Talking Points

by "PLATELAYER"

TOPICAL COMMENT FROM THE MAIN LINES AND SIDE LINES OF METAL FINISHING

CHROMIUM ON THE DEFENSIVE

CHROMIUM plating, which has had a very long and undisputed monopoly as being almost literally the only practicable finish for the bright parts of motor cars for the past quarter of a century, now looks like having to meet some very tough competition. During the past eighteen months production of stainless steel for the motor industry in this country has trebled, and the recent sharp reduction in the price of ferritic stainless strip should make the use of the material even more attractive.

In the U.S.A., the weight of aluminium used for bright trim on the average motor car also almost doubled last year as compared with the previous twelve months.

Of course, these gains were not all obtained at the expense of chromium, since changes in design involving the use of more bright trim, and also increased car production in this country account for some of them.

The alternative materials are not having it all their own way, however ; neither of them have quite the brilliance of good chromium plate, while cost considerations and plant availability also play their part in keeping chromium plate in the lead. Nevertheless, it is a fact that neither the designers nor the general public have much confidence in the durability of chromium plate on motor cars. Buyers are, to some extent, to blame for being unable to distinguish between good chromium plate and bad (admittedly, a tricky technical problem) or to pay for the better product even when they can get it, which is not always the case.

The big problem facing those companies which have an interest in the continued expansion of nickel and chromium plating (and they are by no means confined to platers alone) is to ensure that the quality of chromium goes up, and stays up, and that the shoddy producers are eliminated. There is room for some corporate action — but by whom ?

DEEP SCHEME

A NEW approach to the effluent disposal problem, which has already been employed in Germany and the U.S.A., will soon be tried out in this country, apparently. This consists in pumping the effluent through a deep-bore hole into the underlying rocks — a reversed artesian well, in fact. Drilling the borehole to a depth of 2,500 ft. or more is a costly affair, but as against this, very considerable quantities of effluent can be disposed of into a single borehole which may be jointly owned by several firms. Of course, solid material must be removed from the effluent by sedimentation or filtration, if clogging of the absorptive zone is to be avoided. Likewise, care must be taken by analysis of the water in the borehole, to ensure that precipitation does not occur as a result of interaction between the effluent and the water, which may also put the system out of action.

One possible danger that will have to be watched is the potential contamination of artesian wells drawing water from the same rock sources. Such wells are normally considered safe sources of supply, but this situation may change rapidly if the new system becomes popular, specially in densely occupied areas.

THE COST OF INFORMATION

GETTING information to potential customers is an essential, and relatively costly part of the activities of a business. A recent estimate of the relative costs of different methods of approach by the chairman of an engineering concern in a letter to the press is interesting. A printed circular and a leaflet costs 1s. 6d. per addressee, an individual letter 5s., an exhibit at Olympia costs 10s. per leaflet collected, and sending a representative costs £3. A full page glossy advertisement costs 1d. per copy.

These figures are significant but their interpretation is a more precarious matter. It is notoriously difficult to assess the cash value of advertising or exhibiting at trade fairs. Who can say whether sending a representative is worth the price of 720 full page glossy advertisements ? All one can be fairly sure of is that firms which cease to advertise themselves effectively in one way or another lose leadway very quickly.

THE RETURN OF DA VINCI ?

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Some Considerations in Relation to the HOT-DIP GALVANIZING of GUARD RAILS

by H. BABLIK, F. GÖTZL, and E. NELL

HAVING regard to the possible mechanical stress to which guard rails are liable to be subjected, hot dip galvanizing is a far better protection against rust than is paint which requires periodic renewal.

When guard rails are installed in rural regions, *i.e.* in an atmosphere which can be described as "pure fresh air" where the corrosion of the zinc coating is about 7 gm. per sq. m. per year, the thickness of hot dip galvanized coating required to give a life of 30 years should be about 250 gm. per sq. m.

But when the guard rails are installed in an industrial atmosphere, polluted with gaseous industrial effluent where the corrosion of the zinc coating is about 40 gm. per sq. m. per year, the corrosion will be 1200 gm. per sq. m. within 30 years. The thickness of coating therefore should be between 250 and 1200 gm. per sq. m. of surface according to the severity of the local conditions.

Coatings of this order are difficult to obtain on guard rails. In view of the mechanical strength, which they are required to have, guard rails are normally manufactured from a steel with a strength of 70 kg. per sq. mm. containing 0.6 to 0.7 per cent carbon and 0.1 to 0.2 per cent silicon, the carbon being present almost entirely in the form of lamellar pearlite. This means that there are elements in the iron present which leads to a considerably accelerated reaction between the base metal and the molten zinc during galvanizing.

Another interesting point about this reaction, which can be encountered also in galvanizing of other components, is the difference between the rate of alloying which occurs between the zinc and the original surface of the guard rails, and that which occurs when this original surface is removed by filing. Although this fact has been known for some time it is not, up to the present time, possible to offer a satisfactory explanation for the difference.

Fig. 1 shows in section the edge of a guard rail, which after the usual pickling and flux treatment, has been dipped for ten minutes into a bath of electrolytic zinc containing 0.06 per cent aluminium at a temperature of 450°C. The horizontal interface is the original rolled surface of the rail, while the vertical interface is the underlying metal after the surface structure has been removed by filing.

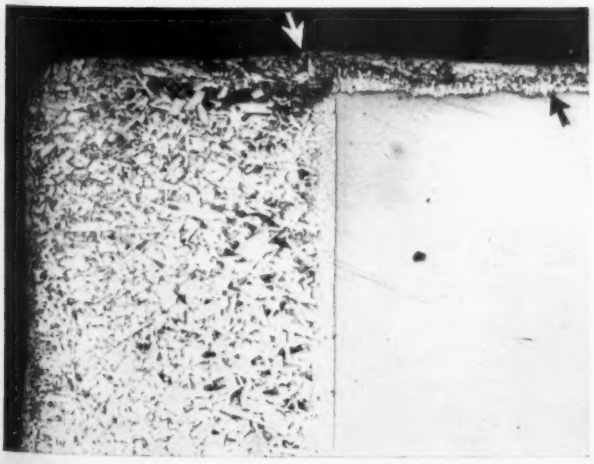


Fig. 1.—Microsection of the edge of a galvanized guard rail on which the original metal surface (horizontal) and a new surface exposed by filing (vertical) are indicated by the arrows. The sample was dipped for 10 minutes in a zinc bath containing 0.06 per cent aluminium at 450°C. x 150.

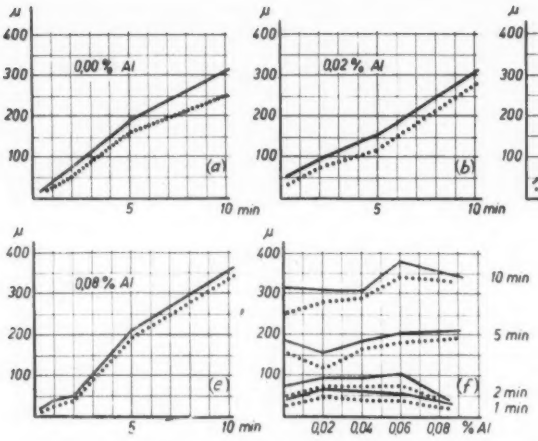


Fig. 2.—(a-f). Curves showing increase in thickness of total coating (solid line) and of iron-zinc alloy layer (broken line) with dipping time at varying concentrations of aluminium in the bath. The original surface of the guard rail has been removed by filing to expose the underlying metal.

The extensive formation of the iron-zinc alloy layer consisting mainly of ξ crystallites can be easily seen. The increase of thickness of this layer is in direct linear proportion to the time of immersion, *i.e.* about 30μ per min.

The essential difference in the reaction of the two types of surface is that they react differently when aluminium is added to the bath. While the original surface and the surface exposed by filing may show no difference in reaction on immersion in a bath of pure zinc, considerable difference is manifested when aluminium is added to the bath. In the case of the original surface the position is normal in that the iron-zinc reaction is reduced by the addition of aluminium in the usual concentrations. On the other hand, in the case of the underlying metal the addition of aluminium up to 0.08 per cent has no effect on the reaction with zinc and the formation of an alloy layer.

This fact is brought out in the curves in Fig. 2 where the broken lines show the thickness of the alloy layer and the full lines the total thickness of the coating. It is quite remarkable that in such thick coatings nearly the whole thickness should consist of iron-zinc alloy layers. Furthermore, as can be seen from Fig. 2f, the thickness of coating

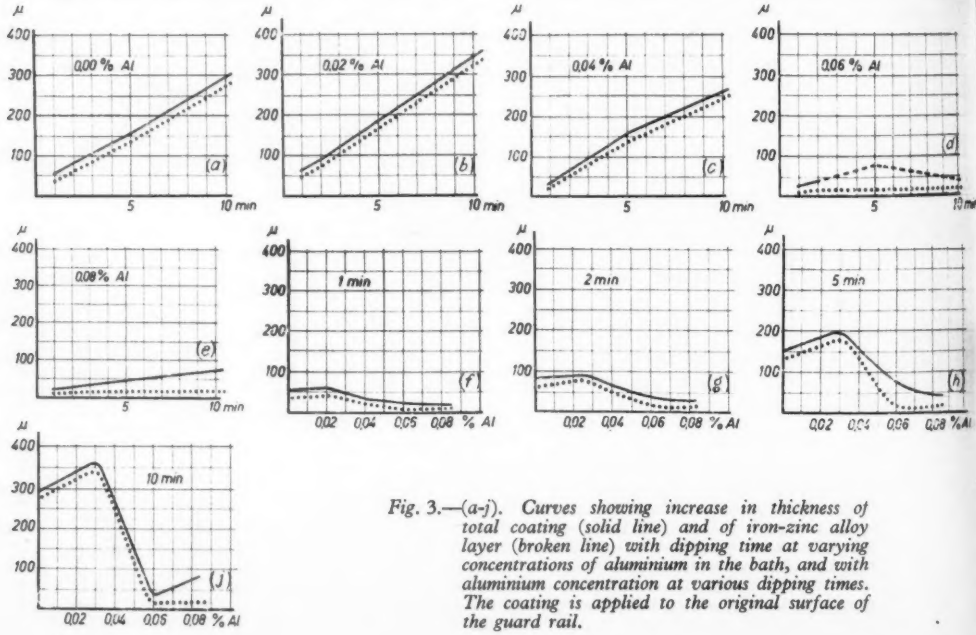


Fig. 3.—(a-j). Curves showing increase in thickness of total coating (solid line) and of iron-zinc alloy layer (broken line) with dipping time at varying concentrations of aluminium in the bath, and with aluminium concentration at various dipping times. The coating is applied to the original surface of the guard rail.

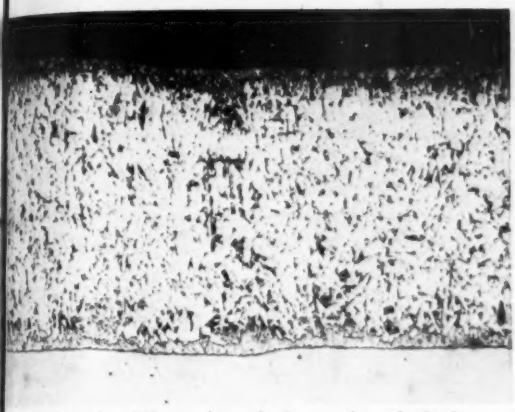


Fig. 4.—(above). Microsection of the coating obtained on a guard rail, from which the original surface has been removed by filing, after dipping for 5 minutes at 450°C. in a zinc bath containing no aluminium addition. x 150.

Fig. 5.—(right). As in Fig. 4, but with the addition of 0.08 per cent aluminium to the zinc bath. x 150.

is independent of the aluminium content of the bath. This Fig. also shows that after a dipping time of 5 min. the coating thickness is about 1400 gm. per sq. m. while after 10 min. it is about 2100 gm. per sq. m. A comparison of the two sections (Figs. 4 and 5) shows that the structure of the coating appears identical when aluminium is absent and when it is present to an extent of 0.08 per cent.

On the original metal surface the effect of the addition of aluminium to the bath is quite different. This fact is brought out in Table 1 and the curves shown in Fig. 3 where the thickness of alloy layer and total thickness of coating in relation to dipping

(*Continued in page* 300)

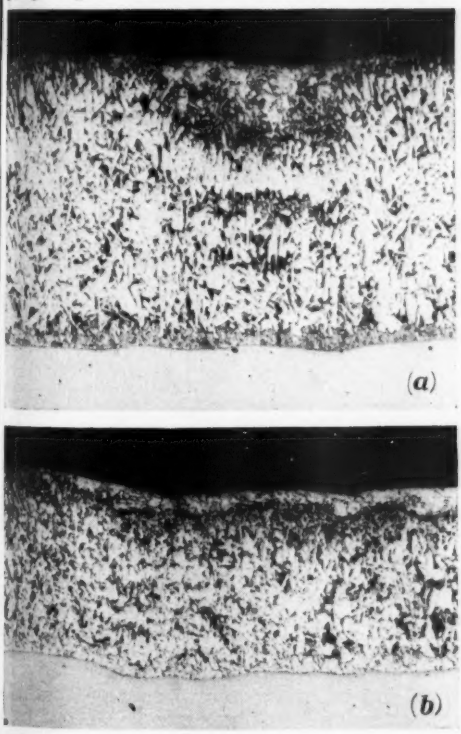
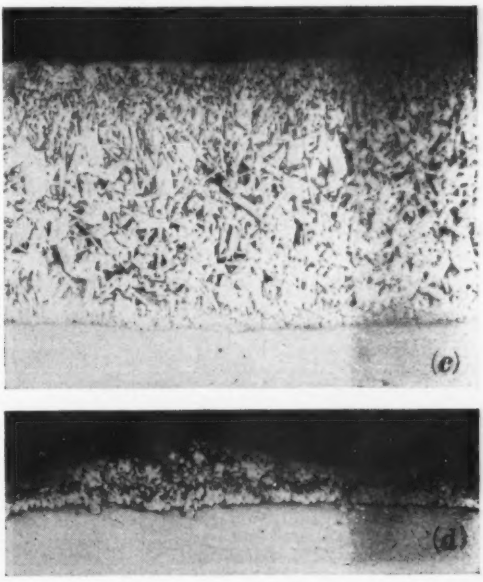


Fig. 6.—Microsection of coatings obtained on the original surface of guard rails after dipping for 10 minutes at 450°C. in zinc baths containing (a) no aluminium; (b) 0.02 per cent aluminium; (c) 0.04 per cent aluminium; (d) 0.06 per cent aluminium. x 150.



FINISHING POST

A SELECTION OF READERS' VIEWS COMMENTS AND QUERIES ON METAL FINISHING SUBJECTS . . . . .

Advice on all aspects of metal finishing practice is offered on these pages, and while every care is taken to ensure the accuracy of information supplied no responsibility can be accepted for any loss which may arise in respect of any errors or omissions.

Anodized Aluminium for Heat Reflectors: A Comment from the Consumer Advisory Council

Dear Sir,

I do not feel that your comment* on our remark about anodized *versus* polished aluminium is fair comment.

It has been found that there is an appreciable risk that anodized aluminium will craze when used as a heat reflector, and, to our knowledge, one of the biggest producers of electric fires in this country has virtually discontinued the use of anodized aluminium for reflectors on their fires for this reason.

Yours faithfully,

ELIZABETH GRUNDREY,
Shopper's Guide ", Editor.

** See " Talking Points " METAL FINISHING JOURNAL, May 1958, p.154.*

" Platelayer " says :—

Under some conditions and with certain types of anodic film, crazing may occur when anodized aluminium is used as a heat reflector. Such crazing is, however, not very significant, and an anodized reflector surface, even when the film is crazed somewhat, is much more durable than unprotected aluminium. Anodized aluminium is still very widely used for heat reflection.

Hot-Dip Galvanizing of Guard Rails

(*Continued from page* 299)

time and aluminium content of bath are plotted ; these show that aluminium contents greater than 0.04 per cent exert a considerable inhibitory effect on the iron-zinc reaction. The particular values obtained for aluminium contents of 0.04 and 0.06 per cent make an interesting comparison. At above 0.04 per cent aluminium the coating thickness undergoes a rapid and quite remarkable reduction. For example, for a given dipping time of 5 min. the thickness of the coating at the lower aluminium value is 1085 gm. per sq. m. while at the higher value this falls to 560 gm. per sq. m. With a dipping time of 10 min. the difference may be exaggerated so that the higher thickness at the lower aluminium level may be 1785 gm. per sq. m. which at the higher aluminium level falls to 214 gm. per sq. m. This fact is quite impressively shown in the series of micro sections reproduced in Fig. 6.

It follows from this that the only way in which it is possible to produce a zinc coating of adequate thickness to meet service requirements of guard rails is by making the proper addition of aluminium to the galvanizing bath. Even under the most favourable climatic conditions guard rails require a minimum coating of 250 gm. per sq. m. and in corrosive conditions it is quite often necessary to give a coating of 600 to 800 gm. per sq. m. Therefore, as the coating has to be applied to the original as rolled metal surface, the only control possible over the thickness of the coating is by regulation of the dipping time. If for example, it were possible to work in such a way that guard rails remained for only 2 min. in a zinc bath entirely free of aluminium, this would result in the formation of an alloy layer 60μ thick. On withdrawal from the bath this would acquire a pure zinc coating 30μ thick, giving a total thickness of 90μ which corresponds to a coating of 630 gm per sq. m.

It would in fact not be possible to manipulate the guard rails in the galvanizing bath in so short a time, and in practice in order to provide for proper removal of the flux coating a dipping time of 5 to 10 min. would be required, giving a coating of 100 to 2000 gm. per sq. m.

Because of the special nature of the metal used for the manufacture of guard rails, it is highly desirable to give them a coating of such thickness as will protect them even in strongly corrosive environments for their probable life.

Table I

Thickness in μ of total coating and iron-zinc alloy layer obtained on original surface of guard rail at various dipping times and aluminium concentrations.

Aluminium Content, per cent.	Dipping Time 1 min. total	1 min. alloy	2 min. total	2 min. alloy	5 min. total	5 min. alloy	10 min. total	10 min. alloy
0 00 to 0.02	53	41	76	63	156	140	290	278
0.02	58	47	82	72	175	166	338	332
0.04	32	24	65	50	155	140	255	247
0 06	23	5.5	34	9 5	80	12 5	30 5	18
0 08	20	4	28	7.5	45	14	77	16

THE INSTITUTE OF METAL FINISHING

1958 ANNUAL CONFERENCE IN TORQUAY

Report of Technical Sesssions

(*Continued from page* 180, *May*, 1958

Abstract No. 9.

Some Aspects of the Growth of Electrodeposits

by H. J. Pick, B.Eng., Ph.D. and J. Wilcock, B.Eng., Ph.D.**

THE properties of a metal depend upon its microstructure and on the nature and distribution of any impurities present. Considerable investigation and research has been devoted to developing means of producing the desired microstructure in metallic components by various working sequences and by heat treatment. While the properties of electrodeposits are equally dependent on their microstructure, methods of improving these properties have up to now been evolved almost entirely by empirical methods.

Electrodeposition is only one of several methods of growing metal crystals and the introduction to this paper briefly reviews published work on other methods of growing crystals. It then describes a method of observing and recording photographically at high optical magnification the process of electrodeposition of copper from acid copper-sulphate solutions. Some results obtained by this technique during an investigation of deposition on single crystal and polycrystalline cathodes are reported. These results illustrate growth by the spreading of layers and the formation of crystallographically well-defined surface features, details of which are dependent on the crystallographic orientation of the cathode surface. Observations of growth by the self-propagating spiral step mechanism are also reported.

*Department of Industrial Metallurgy, University of Birmingham

Discussion

DR. D. N. LAYTON (Manager, Dudley Factory, Ionic Plating Co., Ltd.) said that there was still an enormous gulf between theoretical examination of crystal growth and industrial practice, but it was encouraging to find that the authors, in common with a number of other people in this country, were not discouraged but rather stimulated by the gulf.

The authors thought that they might be able to improve on the present empirical method within the next decade or two. Twenty years was a long time, and he thought that they were being a little pessimistic.

Dr. Wilcox pointed out that the paper was a study of the actual crystal growth, but there was a great deal to be done on the electrochemical side as well.

He was particularly interested in the plate structure or lines and ridges the authors found in the growth of copper crystals. Dr. Layton did some work on both single crystals and polycrystals of iron and it was very noticeable that similar plates formed parallel to the cube edges of the iron crystals. This happened on cube faces of (110) the most densely packed face, and faces like (310) which were quite markedly inclined. There were ridges and spurs on the ridges on the faces parallel to cube edges. An edge grew across the face and that corresponded to the cube edge This was consistent with what the authors found on copper.

The authors' technique did show what was happening and it allowed continuous comparison of what was going on in different instants of time.

MR. E. A. OLLARD (Director and Consultant Electro-Chemist, Atlas Plating Works Ltd.) said that in electrodeposition the main interest was in exactly what happened between the time the atom got itself out of solution and finally came to rest in the lattice.

These diagrams, were, however, static diagrams whereas at the average temperature at which work was normally carried out the atom was not entirely static. It did not move at anything like the speed or anything like the distances of an electron ; but it did have a certain amount of vibration. Although it might be difficult for the atom to change its position very quickly with regard to other atoms in the lattice, it was known that in certain circumstances it could do so, because diffusion of one metal into another was common.

The diagrams therefore, provided the probability of an atom being in a certain place at a certain time, they did not actually state that it would be there.

MR. S. H. MELBOURNE (Research Chemist, G.K.N. Group, Research Laboratory) said that Dr. Pick had stated that the time required for the appearance of isolated growth centres increased with increasing inclination of the cathode surface to a (100) plane ; Dr. Wilcock had also mentioned this during the showing of the film.

Could he say how definite and reproducible that effect was and could he give some explanation of it ? His own impression was that when plating on to a cathode which was perfectly parallel to a (110) plane, the opportunity for the spreading of layers was necessarily limited and so, in agreement with the observation, fresh nucleation must start very soon in the plating process ; whereas as one departs from this plane, there was more opportunity for the primary spreading of layers and so secondary growth did not have to come in until later on. Was this correct ?

The authors also referred to deposition from a solution containing only half the concentration of sulphuric acid. Dr. Wilcock had said the work was purely metallurgical, but there was a change in the electrochemical characteristics of the work, and he would like to know if this had any direct bearing. If so, what was the explanation of the fact that this was the only time when the spiral growth was observed.

MR. R. A. F. HAMMOND (Head of Branch A.R.D.E., Ministry of Supply) said that the observation on spiral growth was confined to a set of conditions in which two changes were made ; first, polycrystalline plates and second, a reduction in the sulphuric-acid concentration of the solution. He would like to ask to which of these two changes the authors attributed the incidence of spiral growth.

If it was attributed to the change in acid concentration, was it possible that the mechanism whereby the spiral growth was introduced and the process of normal crystal growth interrupted, might have been due to the deposition of basic material at the lower acidity ; if this was so, had the authors done or contemplated doing any chemical analyses on deposits produced under these conditions to see whether or not the oxygen content confirmed or otherwise that theory.

DR. T. P. HOAR (Cambridge University) said he was particularly concerned with what happened when an atom came down on the surface. He thought that it was possible to get a certain amount of evidence, not quite so direct as the photograph evidence, from the kinetics of the electro-chemistry of the process.

In the work of Volmer and Parsons and their School and of some of the Germans during the last ten or fifteen years, there was an interpretation and analysis of the details of polarisation curves which could lead to suggested explanations as to whether an atom arrived at the surface and ran along to the edge of the " screw " where it was deposited, or whether it had to be deposited actually at the edge of the " screw " before it could form part of the growing screw, while anything deposited at other places bounced off.

It was necessary always to consider other evidence as well as the purely photographic or metallurgical evidence. The electrochemical and kinetic evidence, suitably interpreted — and fortunately the mathematics was not complex — would eventually tell more.

THE CHAIRMAN (Dr. G. E. Gardam) asked whether Dr. Pick thought that individual atom layers were being seen or was it not more probable that blocks of perhaps one hundred atom layers, as originally thought by Volmer, then a pause, then another large number of layers were seen.

Using an analogy from bricklaying, the bricks were brought up in a lorry and it was necessary to accumulate a certain number of unlaid bricks adjacent to the site before laying them in an orderly sequence. After one was used another was drawn forward. There was a certain supersaturation that had to be obtained at the immediate surface before a deposition could be made. It looked on the film as though there was rather more than one atom layer.

If an examination is made, across the grain, of a cross section of large copper deposits twinning could be seen. Would Dr. Pick say how twinning was associated with this.

Mr. Hothersall had pointed out many years ago that under certain conditions it was possible to grow whiskers on a copper deposit. They grew out at an astonishing speed and were perhaps $\frac{1}{2}$ cm. long, in quite a few minutes ; they appeared to be single crystals with a pyramidal top. This had also happened in other metals but perhaps because most of the surface was filmed in some way a nucleus only appeared in one place. Had Dr. Pick any views on that ?

It was possible to electrodeposit on mercury, a liquid metal, and when it was deposited an atom entered into the liquid and there was no particular crystal orientation. It was also possible to deposit metals on to solid mercury assuming an electrolyte, liquid at the freezing point of mercury.

Would not there be a difference in the energy required to put the atoms into a lattice of solid mercury as compared with liquid mercury ? Would not that be concerned with the point the president had made ? In the liquid the atom could " pop in " just where it was wanted ; in the case of the

solid it was necessary to bring it to the surface and to move it along until the right place for it to go in had been found.

Author's Reply

Dr. H. J. Pick referred to the comments that various techniques had to be used in order to get a complete picture. This was, of course, true and at Birmingham he was striving to employ more than one technique. What had been seen was one particular aspect of the work, the bulk of which was not done on the microscope, using a cine-camera, because in the very nature of this technique it was not possible to make a very detailed study of the surface features. The electrochemical conditions were not too good, because the objective is very close to the electrode surface and tended to shield it. The bulk of the work had been done by plating in a beaker for a succession of times and then studying the surfaces by X-ray diffraction, optical goniometry, interferometry and so on.

An interesting question mentioned by Mr. Ollard and the President was how an individual atom was transferred from the solution to a position in the crystal lattice. He did not think that it was necessary to know what the individual atom did. The observed features involved a large number of atoms and therefore thermodynamics could be used to make inferences about the kinetics of the overall process. Several such thermodynamic treatments of the process of crystal growth had been published, particularly with reference to the case of vapour deposition.

Unfortunately such treatments were particularly difficult when applied to metals in general and to metals during electrodeposition in particular. Part of this difficulty derived from the fact that it was not easy to estimate the exact change in energy involved in moving an atom from a kink position to a more general position on a surface, even when this surface was in vacuo. When it came to making an estimate of the properties of atoms on the surface of a metal in contact with an electrolyte, the problem became more difficult still. For this reason it was, for example, difficult to predict whether atoms would be deposited at general positions on the surface and then diffuse to kinks, or whether they would be deposited straight into kink positions. The available data would suggest that the latter alternative was the more probable. The activation energy for surface diffusion, in vacuo was, for copper, somewhere between 15 and 20 kilo-calories per mol. The activation energy for the diffusion of hydrated ions in the solution, on the other hand, was probably of the order of 2 or 3 kilo-calories per mol., suggesting that diffusion in the electrolyte should be the preferred process. One could not however be definite even about this, as it was possible that atoms on a surface in contact with a solution might have a lower activation energy for surface diffusion than similar atoms on a surface in vacuo.

As to Mr. Ollard's point regarding the lifetime of an atom coming down from the solution and what distance it diffused, that had been treated by Frank; the calculations he made were given for low-vapour-pressure substances. The estimate was that at room temperature atoms would, on the average, be deposited, diffuse something of the order of 400 atomic spacings, and then re-evaporate again.

For copper the distance would probably be several orders of magnitude higher if one applied Frank's formulae; but it was again difficult to say what was happening at a surface in contact with an electrolyte.

Mr. Melbourne had made a point regarding the appearance of isolated growth centres at different times, depending on the orientation. The authors had not carried out these experiments often enough to be certain of the reproducibility, and could only claim self-consistency.

Dr. Pick would strongly avoid using the term "nuclei" to describe the isolated growth centres shown.

Describing the process of crystal growth briefly Dr. Pick said that with an arbitrary "step-type" surface, growth would occur by the addition of atoms to steps. During growth some of these steps would grow faster than others ("Bunching" was the term usually applied to this phenomenon), leading to an increase in step height with time.

A close packed surface, such as the (100) plane contains far fewer steps than say a (310) or (210) surface, and the former therefore contained fewer sites for deposition. The number of steps per unit length of surface in fact increased with inclination of the (100) plane to the cathode surface. It was therefore possible that early formation of growth centres on (100) cathodes might be necessary because of the small number of steps available, although that was not certain in view of the fact that the cathodes were not perfectly flat, but contained undulations typical of electropolished surfaces. The "growth centres" on the (210) and (310) cathodes might well merely be the result of localized "bunching."

On the effect of acid content on spiral formation, Dr. Pick stated that in the ordinary solutions, which contained $\frac{m}{2}$ — sulphuric acid, the authors had occasionally found spirals, but those were very much the exception. If no acid was put into the solutions spirals tended to become common at higher current densities.

(*Continued in page* 316)

ENAMELLING NEWS LETTER *from our Correspondent in* FINLAND

IN Finland today there are a dozen enamelling shops at work. Commencing as late as 1921 the progress in the vitreous enamelling industry has been quite remarkable. The total tonnage of cast and sheet iron produced last year amounted to some 8,000 and it is of interest to compare this figure with those given by Mr. J. H. Gray (*vide* Vitreous Enamellers Bulletin, 1953) when the total quantity was approximately 2,500 tons.

During the early days there were many difficulties owing to the lack of trained staff, skilled labour and effective equipment. Quite soon, however, there was a rapid change for the better mostly due to the much needed "know-how" given by overseas technicians. Today up-to-date knowledge is obtained, not only from technical papers and reports, but also through frit and equipment suppliers and by our own technicians visiting foreign plants.

The sizes of plants differ greatly, the number of furnaces in the various companies ranging from 1 up to 10.

Although a comparatively new industry, (the majority of plants were established in the fifties) there are some 30 furnaces in operation and of these, two are continuous, while the remainder are of the box type. Electricity is by far the most popular means of heating and it is worth noting that only four furnaces are operated by other fuels—of which one is oil fired, one heated with town gas and two are coal fired. Plant mechanization is of varying degrees.

After World War II there was a boom in the enamelling industry. Often shortages of goods and materials together with heavy government import restrictions made technical and economical utilization of latest improvements in the field of vitreous enamelling difficult or perhaps impossible. It should not be forgotten that only one year ago frits and most enamelling equipment were on the list of restricted goods.

Frits are for the most part imported from England, Holland and Germany, and only very little is manufactured in this country. No lead-bearing enamels are in use, except some new frits for aluminium. Almost without exception acid-resisting enamels are used on cast and sheet-iron holloware and on gas and electric cookers.

About 50 per cent of the firms are manufacturing cast and sheet iron articles, the rest only sheet iron. The chemical composition of the cast iron used for vitreous enamelling does not differ very much between the various works in this country. The phosphorus content is generally held between 0.4 and 0.7 per cent, thus being slightly lower than in the English caste iron used for enamelling. The steel used is not generally of enamelling grade, but rather a good quality cold-rolled deep-drawing steel is used.

Sheet-iron enamelling concerns mainly panels for gas and electric stoves and stove linings, refrigerator interiors, kitchen holloware, washing machine tubs and signs. The architectural enamelling of sheet iron and aluminium panels started last year met with great interest in the building industry.

Cast-iron baths, basins, sinks, parts of heating stoves etc. make about 50 per cent, by weight, of all enamelling. Baths are made varying from small sitting baths to larger sizes. The tendency is to change from ordinary soft enamels to acid-resisting frits, withstanding 10 per cent citric acid. A special article, sometimes puzzling visitors from abroad, is the big cast-iron pot of 50 to 300 litres, enamelled on the inside, made for the Finnish "saunas" (bathhouses). Annealing of cast iron was never popular and is not carried out at all in Finland today. The main reason for this being that most cast iron is processed using a matt ground coat.

Firing and drying do not differ from methods practiced abroad. As a matter of interest it could be mentioned that drying with infra-red continuous type driers is used in at least two companies.

Normally the enamelling shops are operating in 2 or 3 shifts for 5½ days per week, During the last winter there was a recession, even in the enamelling industry, with partly shortened weeks as a result.

Gas and electric cooking appliances are produced in a range of pastel shades in addition to white, but white, perhaps due to conservatism, is by far the most popular. Industrial design, which only a few years ago was regarded with a mere theoretical interest, is today playing an important part in creating better and more attractive appliances.

As there are only two towns in Finland supplied with town gas the bottled gas stove appliances are rapidly becoming more and more popular. Although percentually decreasing, the production of wood-fired stoves is still comparatively high and a change to a more modern appearance is also recognized in this respect. In cooking and some household articles there is an increasing use of vitreous enamelled sheet iron instead of cast iron and this change is expected to be further accentuated.

ELECTROPOLISHING and Related Techniques*

By A. A. TOMKINS†

INTRODUCTION

ELECTROPOLISHING, and the related techniques such as electrolytic smoothing chemical polishing, buffing, brightening, etc., do not appear to be as well known in manufacturing industry as their usefulness seems to warrant. It is proposed, therefore, to deal with the basic chemical and electro-chemical methods of polishing which engineers may find of use. It should be noted that chemical and electrochemical polishing can only be considered as possible replacement for mechanical polishing (*i.e.* a reorientation of the surface by flowing) and not for more or less coarse abrading which involves the removal of bulk material. Leaving aside the methods of obtaining smooth surfaces by the traditional mechanical methods like scouring, burnishing, etc., the simpler aspects of the theories underlying the achievement of smooth, shiny, surfaces by chemical or electrochemical processes are considered and some of the practical applications reviewed, with reference to some large-quantity production techniques, and to the economics of the chemical and mechanical methods. The chemical and electrochemical techniques are simple, the results satisfactory, and their application to engineering manufacture can well be an important contribution to increased productivity industry.

Chemical and electrochemical polishing is not new, for a German patent taken out in 1910 (Weill 1950)‡ mentioned a method of polishing silver in a cyanide solution. There was not much interest commercially until the early 1930's when a number of patents was filed, in France where Jacquet has done important work, and in the United States of America from work at the Battelle Memorial Institute (Tegart 1955). The 1939-45 war gave a boost to the scientific study of the process in the interests of labour-saving and increased production, and several plants were installed for war-time applications. Research workers have found many applications for electropolishing, for it is a method of obtaining a smooth surface which can appropriately be described by the old-fashioned term "elegant," as it is quite unspoilt by mechanical damage. That electrochemical polishing is relatively little used in large-scale production may be due to a lack of understanding of the process, or perhaps the large number of patents taken out on minor variations in solution make-up have surrounded the process with an aura of mystery. In the current usage of the terms, "electro-smoothing" implies the elimination of large irregularities, "electrobrightening" is taken to mean that the smaller irregularities are removed by the process, and "electropolishing," "electrobuffing" in the United States, usually implies that the surface is given a final polish by electrochemical processes after an initial polishing by mechanical means. The term "electromachining" is kept for the bulk removal of metal when several thousandths of an inch may be taken from the surface. In the following notes all the above processes are referred to, for the principles involved are similar, and the lines of demarcation somewhat vague.

THEORY

Simple Dissolution

Most books on electropolishing assume an enviable understanding of the more complex electrochemical processes and start with diagrams of potential differences plotted against current densities, electrolyte concentrations, etc., but the processes of chemical and electrochemical smoothing and brightening are basically matters of common observation, for every schoolboy who cleaned a halfpenny in nitric acid will have noticed a loss of sharpness on the raised pattern. Those who fumbled badly when the time was judged right for retrieving the coin from the fuming acid will remember their fears that the whole thing might be dissolved completely. The application of simple electrochemistry sought to avoid such anxiety.

Simple dissolution, which by itself does a more useful job of smoothing than generally seems to be realized, can be confirmed by a pair of dividers and a scale drawing. Fig. 1 represents a section across part of a halfpenny. The original section of the edge of the coin and a portion of the lettering and the central raised pattern might be as at *a*. When it is immersed in a medium which dissolves the surface uniformly, taking, say, 0.001 in. away all over the surface, the form remaining would be

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† Chief Chemist, Joseph Lucas Ltd.

‡ An alphabetical list of references is given at the end of this paper.

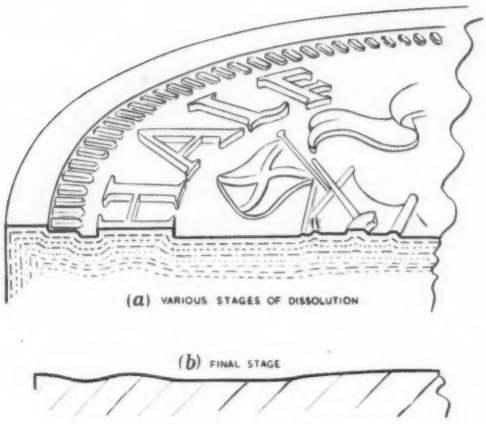


Fig. 1.—Stages of dissolution.

Fig. 2.—Section of roughly machined surface.

as shown by the broken line. A further layer dissolved away, will leave, plotted as before, the shape shown by the dotted line. A further layer dissolved away, will leave, plotted as before, the shape shown, by the dashed line. Successive further dissolutions will leave the section shown in Fig. 1*b*. Still further plotting will show that by uniform dissolution any irregularities on a surface will change to larger and larger radii. The smoothing so obtained will be more efficient if the surface irregularities are close together than when they are widely spaced. This will be seen from a consideration of the geometry. Fig. 2 is of a section of a roughly machined surface with closely spaced and widely spaced ridges, and with successive stages of dissolutions plotted. It will be seen that the closely spaced ridges have their radii well merged into one another, while the more widely spaced ones are not so well smoothed. Fig. 3 is a photomicrograph of a piece of metal deliberately ridged to show this, and to show successive stages of dissolution. It will be seen that the predicted results are in reasonable agreement with those actually obtained.

From Figs. 2 and 3, two fundamental lessons can be learnt : (1) that widely spaced irregularities are not so successfully polished by dissolution as are closely spaced irregularities, and (2) the surfaces left by dissolution are not necessarily perfectly plane since some " waviness " is usually present, although they are microscopically smooth and bright.

Control by Electrolysis

The anode and cathode in an electrolytic cell passing current lose and gain matter respectively at a rate proportional to the quantity of electricity passing or, as Faraday's law has it $W = IEt$, the weight lost or gained (from anode or cathode respectively) is equal to the product of the current, time, and a factor called " the electrochemical equivalent " of the substance concerned. This fact is of use in the classical methods of measuring current by means of silver or copper electrolytic cells (voltameters), where the anode and cathode

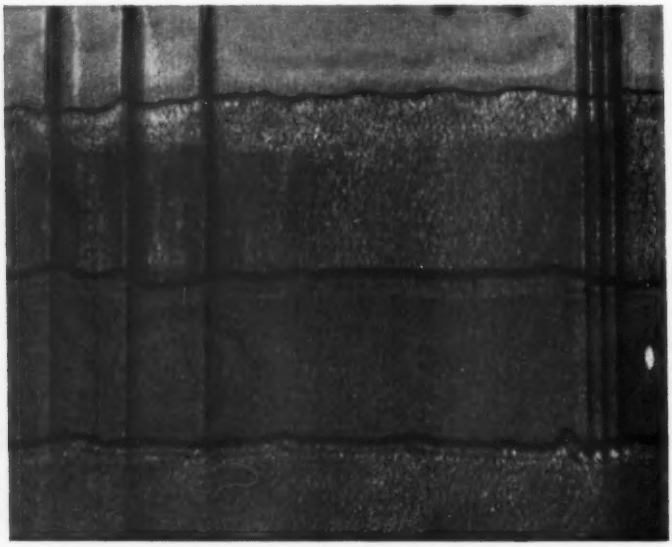


Fig. 3.—Ridged metal (showing merging of closely spaced ridges and successive stages of dissolution.)

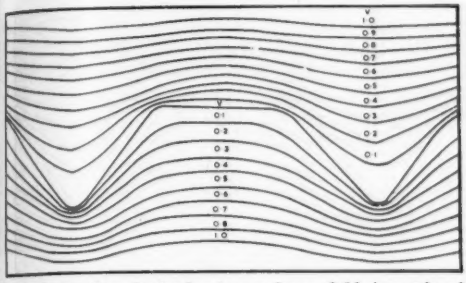


Fig. 4.—Results obtained when voltage field is explored with a probe.

loss and gain can be determined by weighing, the time readily checked, and, the electrochemical equivalent of the substance transferred being known (it is numerically the chemical equivalent divided by 96.540) the quantity of electricity which has passed through the cell can be determined. The anode of the cell would probably become smoothed during the operation.

For rough and irregular surfaces the above relationship $W = IEt$ still holds, for it is the total quantity of electricity, the product of the current and the time, which is involved. But any irregularities seriously influence current distribution; really uniform current distribution can be achieved only between electrodes of simple geometric form, such as concentric spheres, concentric cylinders, or electrodes at opposite faces of a rectangular box. Irregular shapes do not permit easy determination of spot-to-spot current density, for equipotential surfaces must first be plotted and, remembering that current flow must be at right-angles to them, then current distributions plotted. This is complex enough in two dimensions to raise doubts as to considering the normal three-dimensional case, but those interested might like to consult the comprehensive series of papers by Kasper (1940, 1942).

For an insight into the two-dimensional case the work of the B.N.F.M.R.A. on electropolishing (Edwards 1951-52) should be consulted, but briefly the method employed was to make a large-scale model of the surface of the electrode in a shallow tray of electrolyte and to use a small probe to explore the voltage field. Fig. 4 shows the results obtained.

However, it is not difficult to appreciate that for a cone-shaped anode with its apex facing a plane cathode, the current density will be at maximum at the apex and at minimum at the base. Electrochemistry can thus help chemical dissolution; for as the current density is higher at those parts of the surface which project toward the cathode, then IEt will be higher for this particular spot than for places of lower current density, and the rate of dissolution here will consequently be greater. It must be pointed out, though, that this simplified explanation of what is called "primary current distribution" takes no account of polarization, gassing, etc., or the even more complex effects brought about by changes in the concentration of the electrolyte at specific points.

Secondary Effects: Viscosity and Passivity

To consider these secondary effects in any detail would not be of much service to practical engineers, although to neglect them altogether would tend toward over-simplification.

If a metal anode with an irregular surface is placed in an electrolytic bath, as soon as current passes, the anode material will dissolve in the electrolyte surrounding it. By careful selection of the electrolyte it is sometimes possible to arrange that the anode material which goes into solution increases the viscosity of the electrolyte with which it combines. It is easy to see that such a fortunate happening would materially assist the removal of projections from the anode surface, for the relatively viscous liquid would be more likely to remain in the hollows and be removed by diffusion from the ridges or peaks into the main bulk of the electrolyte. The selection of electrolytes of suitable viscosity, and the "matching" to this of the optimum degree of agitation can be an important feature of the process. Viscosity has an influence on current distribution, for the relatively viscous liquid in the crevices which is rich in ions from the anode, will not so readily take part in the electrolysis as the "fresher" electrolyte on the peaks and ridges. Similar effects take place if the electrolytic bath is not a solution but a fused salt.

Again, metals tend to become "passive," which is another way of saying "not-so-reactive," and this is usually ascribed to the formation of a film of protective substance on the surface of the metal. Electrolytic baths seem to be especially well able to render metals passive, for passivation is often aided by the presence of oxygen ions. Electrolysis in aqueous solutions liberates oxygen at the anode, and these oxygen ions are more likely to remain in the crevices than on any points or ridges of the surface by reason of viscosity.

It will be seen that these apparently secondary effects, viscosity and passivity, are of considerable importance in the mechanism of electropolishing, although they may not be understood completely. It is perhaps this lack of complete understanding which makes the discovery of new electrolytes such a popular field with inventors seeking patents. However, research is going on and the time should not be too far distant when some at least of the secondary factors have been elucidated, and tertiary ones of even greater importance doubtless discovered.

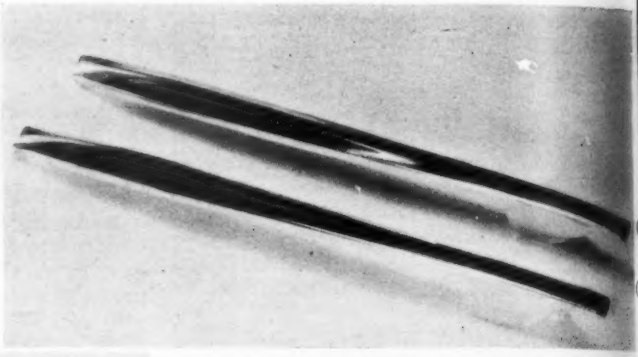
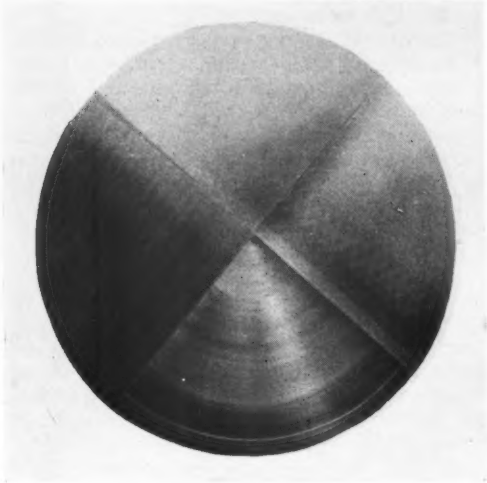


Fig. 5.—(right) Trafficator arms (a, well rolled; b, badly rolled).

Fig. 6.—(below) Piece of test-disc with halves of normal and well-finished quadrants electropolished.



APPLICATIONS

The commonest application of electropolishing is to smooth and brighten components pressed from cold-rolled metals or where intricate shapes preclude the use of ordinary mechanical polishing, for example, articles made of thin strips or wire like bird-cages, cake stands, etc. From the above simplified theoretical considerations, widely spaced irregularities on the surface, for instance, from die-marks on pressed pieces or from roll-marks on the strip prior to pressing, are unlikely to be electropolished successfully. Pure metals electropolish the most satisfactorily; "mixed" metals with diverse electrochemical properties are not so easily electropolished. In the author's experience of the electropolishing of stainless iron for the covers of trafficator arms the avoidance of roll-marks has been the biggest problem in quantity-production application of electropolishing. Components from "well" and "badly" rolled stock show how persistent these roll-lines can be (Fig. 5). The appearance of electropolished plane surfaces is often thought at first glance to be dull, for there are no fine scratch-marks to catch and reflect the light, as with moulds for transparent plastics components which have to have an "optical" finish, their lack of scratches makes them appear "black" rather than "white." Indeed, a useful application of electropolishing would be for tools for plastics mouldings, but no large-scale use of such a process appears to have been made. Fig. 6 shows a piece of a test-disc made many years ago to emphasize the need for good surfaces: "halves" of normal and well-finished quadrants have been electropolished, and while the photograph does not show the improvement very clearly the results are sufficient to warrant the toolmakers' interest.

One application seems to contradict the principle noted, namely, the "de-burring" of cut or frayed edges by electrolytic means, but remembering the edge of the halfpenny it will be seen that even simple dissolution should be successful; and aided by electrolysis even more so. Electrolytic de-burring is especially useful for awkward "inside" edges, where the main surface of the component must not be damaged by file or grinding-wheel marks, and where the shape of the component or the small quantities involved are not favourable for mechanization. An example is the de-burring of clutch plates for a starter motor, a job that took a skilled operator 15 min. each (and even then rarely were all satisfactory) but which by electrochemical means are done 6 at a time in 3 min. without failures.

Cast components are not usually electropolished successfully unless exceptionally smooth and with the grain of the metal very small and uniform; nor are extruded sections easy to electropolish unless they are of exceptional smoothness with no longitudinal ribs or valleys.

Electrodeposited metals usually electropolish well as might be expected from a sort of "electroplating in reverse"; thus, dull nickel may be electropolished prior to chromium plating if for some reason it is desirable to use dull nickel instead of the modern "bright" nickels. Electrodeposited

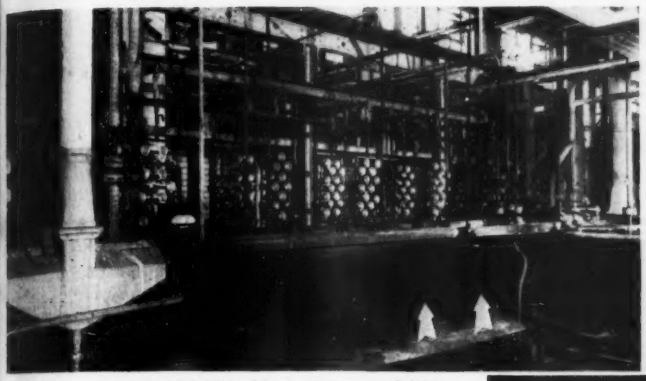


Fig. 7 (left)—Automatic zinc deposition plant (arrows show additional brightening tanks).

Fig. 8 (below)—Effect of electromachining.

chromium does not lend itself to electropolishing. Zinc plating, normally dull and easily fingermarked, is readily chemically polished or brightened by a few minutes' immersion in dilute acids. Fig. 7 is of an automatic zinc plant for electrical components and the arrows show the extra tanks needed for "brightening." The components as they come from the electroplating baths are covered with a faint khaki-coloured film, and a brief immersion in ½-1 per cent nitric acid dissolves this and leaves in its place a thin oxide film which appears to improve the corrosion-resistance of the zinc coating. After swilling, the components are conveyed to a bath of dilute chromate solution for "passivating" which gives a further slight increase in corrosion-resistance.

ELECTROMACHINING

Electropolishing done at high rates of surface removal has been called "electromachining." The mechanism is much the same as for electropolishing, but several thousandths of an inch of surface may be removed. Electromachining has the important advantage of not deforming the surface structure of the metal as ordinary machining does and Fig. 8 shows the difference between parts of a piece of mild steel, one part machined in the usual manner and a neighbouring piece gently "electromachined." It seems quite certain that a good deal of value can come from the development of such technique, for, as more is learnt of "surface physics" and "surface chemistry" there is no doubt that serious disturbances near surfaces will need to be avoided.

Aluminium

An especially useful application of electropolishing is the brightening of aluminium prior to forming on its surface a thin protective anodized layer. Trim on continental motor vehicles, is often done this way; it is hard-wearing, does not rust, corrode, or "season-crack" and is very nearly the same colour and the same lustre as chromium plate. For the brightest appearance and the closest match to chromium it is necessary to use high-purity aluminium which is relatively soft and thus fairly easily damaged by stones thrown up from the road. Some improvement in hardness may be obtained at the expense of a little, but not a serious, loss in lustre by the addition of up to about 2 per cent of magnesium, but the aluminium and magnesium used for the alloy must both be of 99.9+ per cent purity if the sacrifice in brightness is to be small. The need to use high-purity aluminium precludes the use of die-cast parts and limits the choice of form to rolled or extruded sections, with, again, the fear of roll- or die-marks. Such limitations, together with perhaps some conservatism, seem, so far, to have prevented British car manufacturers making the best use of an attractive alternative to chromium plated brass or steel.

Wrought Metal

Wrought-metal components are usually too rough for successful electropolishing without previous mechanical preparation. Pickling generally aggravates the roughness problem by leaving the surface pitted and still more difficult to electropolish; the fault is not with the electropolishing process but with the unsuitable surface common to wrought or roughly rolled materials.

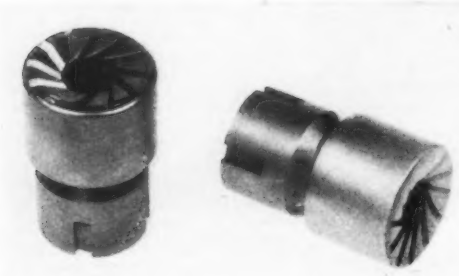


Fig. 9.—Complex nozzle in Nimonic successfully electropolished.

Alloys

Alloys with three or more constituents, especially those containing much silicon, phosphorus, or lead, do not electropolish well because of the dissimilar anodic reactions of the constituents of the alloy.

Steel

Steels, especially stainless, usually electropolish well. Carburizing or nitriding generally gives improved electropolished surfaces, but " nitralloy " steels, particularly those with a high aluminium content, electropolish badly.

Brass

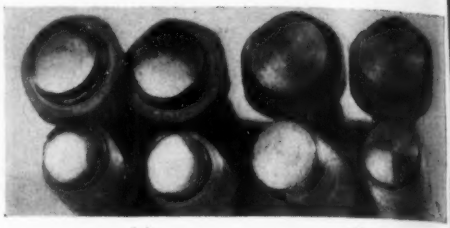
Brass can be electropolished successfully, but the metal should be selected with some care, the 65/35 alloy, being too near the beta-phase, is not so well electropolished as the 70/30 types which work extremely well. Leaded brasses are not easily electropolished, because the lead is electrochemically so different from copper and zinc, and cast brass components are usually too rough.

Silver, Copper, Zinc, and Nickel

Silver, copper, zinc, and nickel, either as plated or in massive form, electropolish readily and well, and electropolishing is becoming increasingly used in the industries employing such metals. Fortunately, many of the newer nickel alloys (such as " Nimonic ") brought out in response to the demands of the aircraft industry for high-temperature-resistant materials electropolish well. Fig. 9 shows a complex nozzle in Nimonic which is electropolished successfully.

Pressure-Die-castings

Pressure die-castings, either in zinc or aluminium-base alloys do not electropolish successfully because the alloying constituents used to make the metal " run well," are electrolytically incompatible with the main constituent. Even if a suitable electropolishing process could be worked out, the removal of the " gate " and " flash " usually leaves areas of fine porosity which seems to show up even more prominently when the adjacent areas are made shiny. Mechanical polishing, unless the porosity is very marked, seems to burnish metal over the pores, the underlying faults are often found later when the component is electroplated, but that is anotner problem.



(*a*) (*b*)

Fig. 10.—Tungsten contact surfaces. (a) electropolished (b) ground

Tungsten

Tungsten is capable of being electropolished successfully in a solution of sodium hydroxide and sodium tungstate, and this has been found of value in obtaining consistent working of tungsten make-and-break contacts in electrical equipment. Fig. 10 shows tungsten contact surfaces ground and electropolished and the difference is very obvious.

PRACTICAL PROCESSES

In practical commercial processes, most of the solutions used for electropolishing are covered by patents, and details regarding the best process for a particular application should be sought from the patent holders or distributors. Most of the patents cover variations in bath composition, current density, temperature, viscosity, etc., to give the required preferential dissolution, but most of those in commercial use are based on phosphoric, sulphuric, chromic, or perchloric acids with additions such as glycerine, glycols, etc.

Solutions

The earliest electropolishing solutions, and still perhaps those used with the widest range of metals, are based on perchloric acid, but this is a dangerous compound liable to explode spontaneously under certain conditions if concentrations are high and the temperature is allowed to rise above 40°C. (105°F.). Plants using perchloric acid should therefore be arranged to be flooded automatically with cold water immediately the temperature approaches, say, 35°C. (95°F.), and even this precaution savours of too touching a faith in thermostats. It will be argued that the perchloriclaceti acid mixtures are well known, and complicated triangular co-ordinate curves will prove that the

bath is safe ; but still, such hazards are not for production shops, nor for laboratories. Against the "proof" of the curves the author recalls only too readily an explosion of a perchloric-acid bath at Los Angeles in America in 1947 in which 17 people were killed.

Perchloric-acid baths have largely given way to less dangerous ones. If the use of perchloric acid is contemplated, the following precautions should be taken :

(1) Keep temperature under 35°C. (95°F.) ; watch possible local over-heating.

(2) Keep concentrations well below 50 per cent by weight of perchloric acid.

(3) Do not use tanks of what is loosely known as "plastics" without consultation, polyethylene is safe, most others are not.

(4) Bismuth forms an explosive compound with perchloric acid, therefore see that there is no possibility of them getting together.

(5) Guard against breakage of containers, even "leaks" or "spilled" perchloric acid concentrating in contact with organic materials (such as wood shavings) will form an explosive substance. Keep containers surrounded with inert non-flammable packing material, such as Kieselguhr.

(6) Do not attempt to distil discarded perchloric acid polishing solutions to recover alcohol, it is dangerous.

(7) Treat the whole process with every possible precaution and respect.

Procedure

Production procedure which may be taken as fairly typical for normal electropolishing is as follows : jig, clean (dip), rinse (or spray), electropolish, rinse (or spray), dry (for electroplating), dilute acid dip, rinse, plate, etc.

Equipment

Equipment is that normally used in plating shops ; tanks of suitable size to take jigs of the work allowing 3-6 in. between the work and the cathodes, and 12-18 in. deeper than the jigs to allow for collection of sludge, are usually of lead-lined steel (although for some solutions lead is not suitable, so advice should be sought early). Cathodes are usually strips of steel, sometimes of lead or copper, hung on the cathode bars. Heating coils are usually provided near the base of the tanks and when large-area work is involved, cooling coils are often necessary as well, to use when the bath reaches working temperature. Resistance (I^2R) losses in the electrolyte are usually high, for currents are heavy and the baths are often of high resistance and so much heating takes place ; a useful rule is to allow 1 litre of solution per 1½-3 amp. (1 gal. per 7-14 amp.). Agitation is usual and often provided by oscillation of the work (anode) rod, although air agitation of the solution may be used in processes in which sludge is not deposited. Since the baths work at quite high temperatures, there is much steam as well as gas evolved as well as some spray, so adequate ventilation must be provided, usually by exhaust over the edge of the bath. Current supply is from motor-generators or transformers and rectifiers and follows usual plating-shop practice.

Conditions typical of the usual run of electropolishing baths are as follows :

Temperature	30-120°C. (85-250°F.)
Current density, amp. per sq. ft.	
Electropolishing	100-500
De-burring	50-700
Electromachining	500-3000
P.D. across bath, volts	5-25 (8-15 is usual)
Time, min.	1-15

Process control is important if consistently good results are to be obtained. It must be remembered that most of the metal removed stays in the bath usually as a more or less soluble compound, it cannot be swept up as can swarf. No hard and fast rules can be given, for some metallic compound residues from electropolishing are sufficiently dense to fall conveniently to the bottom of the bath and stay there as a thick sludge ; others do not behave so conveniently. The usual method of control is to record the number of ampere-hours used and, by experience, put in new solution accordingly, either replacing the solution entirely or by running a proportion of it away and making up with fresh solution. Some components, by their shape, or mere awkwardness, may remove a lot of solution by what platers call "drag out," and normal make-up to replace this loss may be sufficient to keep the solution in good condition. Checks are usually made on viscosity where this is an important feature of the bath's characteristics, and simple chemical analysis as a routine measure will keep a check on the amount of dissolved metal, the limits for viscosity and dissolved metal will readily be provided by the manufacturers of proprietary electropolishing baths.

COSTS

The economics of electropolishing compared with those of mechanical polishing usually favour the former, unless the shapes to be polished are simple enough, and the quantities involved great enough, to warrant the development of fully mechanized production processes where components, "compo," etc., are all fed automatically. Electropolishing plant can range from a beaker on a laboratory bench to a fully automatic plant with 1000-gal. tanks, and costs vary over a similarly wide range.

For the usual mass-produced components which may be successfully electropolished, a typical plant

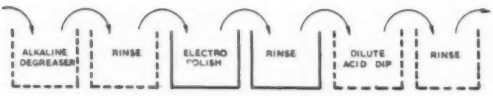


Fig. 11.—Typical electropolishing layout.

layout might be as shown in Fig. 11. It will be seen that such a process may be adapted to fit into a normal automatic electroplating plant, the first baths of which are shown in dotted outline.

Electropolishing economics are attractive. The major costs are those of plant and equipment, and against these must be set the saving in labour charges which are the major factor in the cost of hand-polishing by ordinary mechanical means. On the one hand there are expensive tanks, temperature-control equipment, heavy current-supply apparatus, control-gear, etc., and a multitude of jigs to hold the work ; additionally, solvent or vapour de-greasing plant might be needed although this may also be needed after hand-polishing. For hand-polishing, on the other hand, the first cost equipment is relatively simple and cheap. Labour charges for the two processes are very much in favour of the electrolytic process, especially as it lends itself to mechanization and conveyor-transfer from bath to bath for polishing, swill, rinse, etc., for with, say, one operator jigging the work and another loading, unloading, and de-jigging, the plant will handle many thousands of small components per day. It is not easy to give hard-and-fast comparisons, for components themselves vary in design and material, and in the degree of finish required. An American survey (Faust 1955) showed electropolishing of steel to cost about 6 cents per sq. ft. against 19 cents per sq. ft. for mechanical polishing.

The author's firm has a fairly good comparison in the case of the stainless iron trafficator arm cover, for it is of identical design to the earlier ones in nickel-chromium plated brass, and they have a further check in that they have a figure for the same stainless iron component mechanically polished. The costs, in round figures, show :

	Cost, shillings per hundred		
	Electro-polished (stainless iron)	Hand-polished and plated (brass)	Hand-polished only (stainless iron) (subcontracted)
Materials, per hundred	29	22	29
Labour	4	37	} 29
Charges	11	119	
	44	178	58

It will be seen that while the stainless iron costs a little more than the brass, the labour charges for hand-polishing and plating are nearly 10 times as much as for electropolishing, and this is reflected in overhead charges too, for labour takes space, services, etc. The subcontracted hand-polishing of the stainless-iron components is perhaps a reasonable comparison : 29s. against a total of 15s. for labour-plus-charges for electropolishing, and not too far removed from the American 19/6 ratio. In each case the charges include current, solution "make-up," etc., and, in the case of the subcontracted hand-polishing figure, this presumably includes some profit margin.

SURFACE CHARACTERISTICS

A few notes on the characteristics of electropolished surfaces may not be out of place for, as will have been seen, the material near the surface is much more disturbed by mechanical methods than by electrochemical ones. Oddly enough, if fatigue-strength tests are made comparing electrochemically finished and mechanically finished specimens, it appears that the electrochemically finished ones are inferior, some 20-30 per cent worse. This seems strange when theories show that fatigue failures usually start from some surface irregularities which give locally higher stresses. The explanation which has been given by investigators (Mondon 1956) is that this lower fatigue-strength value from electropolished specimens is really the true value, for mechanical finishing methods introduce a superficial compressive stress which more than offsets the disadvantage of minor surface irregularities. It has been shown, in support of this explanation, that if components which have initially been electropolished are given some subsequent treatment which applies a superficial compressive stress (such as "vapour-honing"), then the fatigue strength is restored and approaches the value given by mechanically finished components.

Another characteristic of electrochemically finished surfaces, which may at first sight seem a disadvantage, arises from the manner in which the electrochemical methods fail to cover surface defects inherent in the material, although these may be masked by mechanical finishing methods, burnished over, as it were. But the defects were there ; that they were hidden may not have been a good thing. Electrochemical finishing as an inspection method might not be unwarranted in the case of important highly stressed components, even though the fatigue strength may have to be raised by a subsequent surface-compressive treatment. The earlier part of this paper in which the simpler aspects of the electrochemistry involved was discussed will have shown the possible use of electrochemical finishing for detecting metal segregation, etc., in alloys.

Concluding what has necessarily been a far from exhaustive account of electropolishing and

(*Continued in page* 316)

PROPERTIES and APPLICATIONS of FLAME-SPRAYED REFRACTORY COATINGS

by Lloyd MANUEL

(*A paper presented to the Annual Conference of the Institute of Vitreous Enamellers, Gleneagles, June 16 to 18, 1958*)

A GREAT deal of information has been published during the past year on the subject of flame-sprayed ceramics for high-temperature application The wide interest in coating materials of this type is largely due to the need for abrasion-resistant thermal barriers on components of jet engines, rockets, and various types of reaction motors.

Ordinary vitreous enamels, which are applied and then fused, are of little use for high-temperature service. Coatings of this type must fuse at a temperature well below the melting point of the metal to which they are applied, and so they will soften at fairly low temperatures, in service. They are not particularly effective as thermal barriers and they have low resistance to thermal shock. These shortcomings have led the designers of high-temperature equipment to look elsewhere for new engineering materials, and flame-sprayed ceramics are receiving a good deal of attention.

A feature of the development of useful applications for flame-sprayed ceramics and cermets has been the advent of the METCO* Thermo-Spray process which has made it possible to apply these materials at speeds and costs which are economically attractive for a wide range of purposes. So far, little has been done with cermets but work with ceramic materials based on alumina and zirconia shows great promise.

Both alumina and zirconia have low thermal expansion coefficients as compared to most metals and alloys. This is essential where coatings must function as thermal barriers, as on parts which receive some cooling influence on the side opposite the coating. There are two reasons why the coefficient of expansion of the coating material must be low. First, a sharp thermal gradient must exist within the coating itself, and a high expansion coefficient would set up stresses which would cause the coating to disintegrate. Second, the mean temperature of the coating will be much higher than that of the metal to which it is applied, so that coating must have a low expansion coefficient to reduce stresses between coating and metal. Ideally, where a thermal gradient exists, a gradient in the expansion coefficient should exist. Composite ceramic coatings, formed by applying zircon over alumina, or alumina over zirconia, are a step in this direction.

Several advantages are apparent for thermal barriers of this type, applied to jet-engine combustion chambers or rocket nozzles for example. First, the high hardness and high melting temperature of the ceramic provides resistance to surface deterioration. Second, the operating temperature of the metal shell is reduced, permitting equivalent strength with thinner sections. Third, the need for super-alloys may be eliminated in some cases, because of lowered operating temperatures. Protection against oxidation may be provided with thin sprayed coatings of heat-resistant alloys beneath the ceramic coating or on the opposite side of the member if required. A fourth possible advantage may reside in increased thermal efficiency of the engine or rocket, since an incandescent ceramic skin would not be expected to cool the outer boundaries of the gas stream as would a much cooler metal surface.

On some parts, such as gas turbine blades of certain types, little or no cooling is possible. For such applications, where the coating and the base metal reach the same temperature, the coating should have an expansion coefficient fairly close to that of the metal. Various cermets have been developed in an attempt to raise the expansion coefficient of the coating and to provide some ductility. Some of these cermets show promise, and are being used successfully on base metals having fairly high expansion coefficients. The use of cermets with the ThermoSpray process is being investigated but it is felt that another approach to the problems presented by this class of work will involve the use of straight ceramics applied to low-expansion metals such as the straight chrome steels. Alumina and zirconia base ceramics will withstand wide temperature ranges when applied to such steels.

The resistance of flame-sprayed ceramics to impact and to abrasion may be greatly improved in many cases by impregnating. Phenolics, furanes, silicones, epoxy-based formulations, and a variety

*The words "METCO" and "ThermoSpray" are Registered Trade Marks.

of other organic and inorganic impregnants have been used successfully. In general those materials which show good physical properties should be used. For example, phenolics and furanes are excellent impregnants. The heat-cured types are preferred, because of superior physical properties, but good results have been obtained with catalyzed or air-dried types.

Some of the properties of alumina-base and zirconia-base ThermoSpray coatings are shown in Table I.

TABLE I

	Alumina	Zirconia
Melting Point	3700°F.	4600°F.
Bulk Density (g/cc)	3.2 to 3.4	5.2 to 5.3
Porosity (per cent.)	6 to 10	6 to 10
Thermal Expansion (per °F, x 10-6	4.3	6.4
Hardness-Moh's Scale	9.0	8.0
Thermal Conductivity * (BTU/hr/sq.ft/in/°F)	19	8
Deposition	15 sq. ft. per hr. 0.010" thick	10 sq. ft. per hr. 0.010" thick
Colour	Grey	Tan-Brown

* On this same scale Stainless Steel (18-8) would read 185 and Carbon Steel 320.

Industry has already found a number of practical applications for alumina-base coatings. Many others are in the testing stage and show much promise. A few of these are listed as follows :—

(1) Coating fan blades subject to abrasion. Fine particles of abrasive have no effect on alumina coatings. Heavy abrasion, as by sand blasting, will break down the coating by impact, but the effect of fine abrasives is negligible. Alumina coatings sealed with a baked or catalyzed phenolic are relatively impermeable and will withstand a great deal of mechanical abuse.

(2) Special corrosion problems may be solved by impregnating alumina coatings with an appropriate sealer. The alumina provides physical-integrity and is completely inert to most chemicals. The sealer may be selected on the basis or resistance to the specific reagent involved, without the need of considering the physical properties of the sealer.

(3) Gauges, surface plates, instrument ways, Alumina coatings may be ground with diamond wheels, or even with silicon carbide wheels, to produce a fairly smooth and very hard corrosion-resistant surface having a low friction coefficient. Impregnation with micro-crystalline wax or other sealants may be used, where corrosive conditions are severe. Solid lubricants such as molybdenum disulphide or graphite may be added to the impregnant, for special bearing applications. Nearly all metals will run against such surfaces with very low friction and no tendency to gall.

(4) Special shapes in lapping plates, hones, grinding burrs, etc. can be made quickly and easily by applying alumina to metal base. Old files, blasted and coated, make ideal " Stones " for light stock removal such as is needed in making bearing fits.

(5) Use on special purpose bearings, processing rolls, filters, mixers or agitator parts, and a host of other possible applications can be expected to develop with time. Even though somewhat porous (6 to 10 per cent.), alumina coatings have a compressive strength in excess of 200,000 lb. per sq. in. Pores may be filled with an appropriate sealer, with a lubricant, or left unfilled as required.

(6) Both alumina and zirconia coatings are completely resistant to nearly all molten metals, although some of the common fluxes, for example zinc-ammonium chloride, will penetrate the coating and attack the base.

These constitute only a few possible uses but a tremendous potential field exists, and development can be expected to be rapid.

* * *

MR. LLOYD MANUEL, presenting his paper said that he had outlined the up-to-date position on refractory coatings by the flame-spraying process; he had also outlined some difficulties due to the high temperatures usually involved and also some technical considerations and applications. The desire for coatings of alumina or zirconia was evident in the United States about four or five years ago for use on guided missiles, generally speaking round the exhaust areas. The United States Government expended about a million dollars on three or four firms and very soon got results in the quickest way, *i.e.* by using ordinary metal-spraying equipment, the wire process of metal spraying, using zirconia in rod form, and feeding it through the gun. The only drawback with that proceeding was the cost of supplying the ceramic in rod form and the slowness of the process. It was slow principally because they had to use ordinary metal-spraying equipment which meant having compressed air as well as an oxy-acetylene flame. Compressed air reduced the flame temperature, giving a slow process. About three years ago a powder-spraying gun was evolved handling alumina and zirconia in powder form which considerably cheapened the process. These were materials which were outside the wire spraying method, because they could not be obtained in a wire or rod form easily. A typical powder spray gun, which had a canister on the top for alumina or zirconia powder, was very slightly larger than that used for vitreous enamelling. When the gun was directed against a component the powder particles hit each other and fused together to give a complete build-up

or deposit. The amount of fusion between each particle was dependent only on the amount of powder sent through ; this could be controlled as also could the speed with which the gun traversed across the work face. There was a small fusion between the particles to get a build-up of alumina or zirconia, but each particle was not completely welded into the other, if the gun was traversed quickly. On the other hand, with a slow gun traverse each particle was fused into the preceding one giving a solid deposit. The difficulty in handling the solid deposit was that it was not possible to add on to thickness. The usual form of deposit from the gun for high-temperature work where a thermal barrier was required was one where the particles were 75 per cent. fused or welded to each other. It gave a coating that was not completely impervious *i.e.* one that would hold together strongly and yet would expand or contract with the face material. Very often to increase the bond strength the coating was "splashed" with ordinary metal spraying of nickel-chrome in addition to the deposit of ceramic. Such undercoatings were necessary if the deposit thickness of ceramic was above 0.015 to 0.020 in. The usual limitation thickness was 0.060 in. unless it has been put on to a very thick component where it was possible to continue building up to $\frac{1}{8}$ in. The deposit could be made non-porous by sealing. When the temperature exceeded 1,000° C. several sealings had to be used. When the temperature rose above 2,000° C. no seals would act. There was very little danger that it would conflict with vitreous enamelling as a finish, mostly due to the fact that the particles always retained their "grain" even if they were fused. Therefore, the finish was almost similar to emery paper, a little more shiny than emery paper was, which made it very difficult to clean or wipe.

Finishing by grinding or lapping was very expensive due to the hardness. Grit blasting, therefore, had to be used ; that usually ran out at 4d. to 6d. a square foot. The deposition of the ceramic was quick, and the raw material costs were less than 10s. a lb. For example, a pound of alumina would give a deposit of approximately 0.060 in. over a sq. ft. Most coatings were of the order of 0.01 to 0.02 in. ; most work done worked out in the region of 2s. 6d. or 3s. 0d. a sq. ft.

In the paper he had discussed only the use of zirconia and alumina, because they were in good supply and used widely. Many other ceramics had been sprayed, and a lot of experiments had been carried out with vitreous-enamel powders. There was usually great difficulty in obtaining special powders which would flow freely enough to be used. There was also a great difficulty if powders did not have such a high temperature resistance as alumina and zirconia, as they tended completely to fuse together and curl up when they were being sprayed and they then separated from the base. Ceramic spraying must be able to take advantage of the grit preparation, and yet it must set in position without running or leaving the base. There was no doubt that the cheapest application was the one the whole process was originally designed for, and that was to apply coatings of alumina or zirconia to get a thermal barrier. Another facet of work which was becoming very important was the use of ceramic coatings purely as an electrical insulator at high temperatures. A lot of atomic work had been done where sprayed alumina was used at temperatures from 2,000 to 2,800°C. The third field which had resulted in a few production jobs was a spray of alumina and zirconia on to mechanical seals, oil seals etc. There were also two firms in production spraying 0.06 in. of alumina on sleeves and shafts. The great cost was the finishing ; the diamond wheel was used but it was very expensive, so the usual way out was to use a silicon-carbide wheel. The wire metal spraying process was now being used for spraying electrical circuits with vitreous enamels, *i.e.*, articles providing direct electrical heating. In America sprayed alumina was used for spraying a circuit and it was of very high resistance, and it was applied to heating panels, washing machines, and refrigerator parts.

Discussion

MR. WATTERS asked if the gun was used on dry process enamels ?

MR. MANUEL said that some firms had experimented with it, but to get the coating completely non-porous it would have to be sprayed hot, but there was great difficulty then in preventing the coating from shrinking and leaving the base. Work had been done in connexion with some reclamation jobs on cheap enamel where $\frac{1}{4}$-in. thick steel plates had been sprayed satisfactorily.

One of the things that had slowed down any experimental work in the field was that it was not possible to see any great advantages in the method over ordinary enamelling practice excepting for repairing defects etc.

MR. BIDDULPH asked Mr. Manuel whether when he was spraying zirconia and/or alumina he was dependent upon the previously blasted surface of the metal to get adhesion or through some reaction between the alumina, while it was hot, and the metal base. It was mentioned that when a coating was built up a thermal shock resistant coating was produced which was not impervious. If that was necessary could it not be obtained by

(*Continued in page* 316)

Institute of Metal Finishing: Conference

(*Continued from page* 303)

Mr. Hammond had suggested that deposition of basic materials might play some part at lower acid concentrations. That was probably a correct analysis, but the authors had no definite evidence. It had been found, for example, that spirals formed from the low acid solution during plating under the microscope but they did not appear when plating in a beaker. In the " microscope solution " there was very little agitation and there was a greater tendency for any impurities to build up. The appearance of visible spirals might well be affected by the presence of impurities, as those would probably lead to an increase in step height. It should of course be noted that their deposits might always contain spirals of low step height, which were not detected by their microscopic techniques.

The step heights of the spirals shown in the film were quite large, probably of the order of 3000°A, and there was still some doubt about the exact mechanism of the formation of spirals with such step heights. In particular it was questionable whether they were in fact associated with screw dislocations. Lang, for example, in a letter to the *Journal of Physical Chemistry* had suggested that hey might be due entirely to assymetrical bunching. Electron micrographs (produced since the paper was submitted for publication) had indicated that the step height of the spirals increased continuously from the centre of the spiral. That fact also was rather difficult to reconcile with a screw dislocation mechanism. It was possible that the spirals seen might have originated at steps produced by intersecting platelets or growth layers.

Whether the use of polycrystalline materials had had an effect on the appearance of spirals was not known, as no single crystals had hitherto been plated in solutions of the lower acidity.

As to Mr. Gardam's point regarding twinning, it was to be noted that cross-sections of thick deposits on cube texture copper always showed considerable twinning. Cross-sections of single crystals plated to their standard thickness of 13.7μ had never shown any twinning. In answer to Mr. Gardam's point regarding the thickness of the observed growth layers, they would like to confirm his inference that the observed growth layers did not consist of individual atom layers ; such layers could not, in fact, be seen under the microscope. They had made no measurements at early plating times, but they knew that they had a height of the order of one micron at a plating time of one hour.

Flame-Sprayed Refractory Coatings—Discussion

(*Continued from page* 315)

a preliminary coating of some other material and then the addition of the alumina ?

MR. MANUEL said that if an undercoating had to be put on to withstand heat there was the problem of preventing the base metal from going. A " flash " coating of the order of 2 to 3 thousandths of nickel-chrome-iron, for example, would prevent that, and would produce a much denser coating than would be obtained with the sprayed ceramic. So far as the preparation was concerned when spraying ceramic on to a grit-blasted base reliance was placed on the base surface to hold the deposit. The only exception to that rule was where an undercoating such as nickel-chrome which had a higher bond strength than sprayed ceramic was used, giving a porous-core sprayed metal. Molybdenum could be used on clean steel to give the same sprayed metal keying. But as the problems of ceramics were usually concerned with high temperatures it was not possible to use molybdenum very often because it would not stand up to more than about 650 to 700°F. The problems due to the porosity of the sprayed ceramics were usually those of lower temperatures where organic type seals could be used. An organic type sealer was better than putting a coat of something else on underneath.

Electropolishing

(*Continued from page* 312)

related techniques of interest to engineers concerned with production, it is suggested that the processes are not as much used as their usefulness, their inherently high productivity, and their economic advantages warrant. If this is because some of the basic principles seemed obscure, or savoured too much of alchemy, it is hoped that the simpler aspects are now better appreciated, and that engineers, no longer fearing the chemistry but remembering that it is merely common sense, will consider the electrofinishing of metal surfaces as a technique well suited to modern production.

ACKNOWLEDGMENT

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FINISHING NEWS REVIEW

PROTECTIVE COATING

A MANNHEIM, Germany, chemical firm has developed a substance based on air-vulcanised synthetic rubber that forms a thin hard film on metals, wood or concrete to form an anti-corrosive barrier, according to a report in a recent issue of *The Financial Times*. The product is marketed under the trade name "Protegol."

SPRAYING TUNGSTEN CARBIDE

Development adds material to hard-facings range

THE addition of tungsten carbide to the range of materials available for hard facing by metal spraying was announced recently by the Metallizing Equipment Co., Ltd., Chobham, Woking, Surrey.

Pointing out that the material has a Rockwell hardness figure of A88-90, the firm says that tungsten carbide should provide excellent wear resistance under extreme service conditions, and might well be the answer to many problems of extreme abrasion.

To achieve good wear resistance, the maximum carbide content is necessary in the coating, says the company, and they claim that this has now been successfully achieved.

Metallizing Equipment say that while straight tungsten carbide can be sprayed, the coating is of little value since the particles are poorly bonded together and the mass cannot be fuzed within itself or to the base. They have therefore mixed the tungsten carbide with a suitable matrix that after fuzing will give a homogeneous coating completely joined to the component base metal.

The new "Metco ThermoSpray" powder will give a deposit efficiency of 93 per cent, containing almost 80 per cent tungsten carbide, the company claims, so that hard facing can be carried out at high speed and low cost.

An important feature claimed for the new material is its very low thermal expansion coefficient, eliminating high stresses during cooling. The firm says that even on straight chrome steels a coating of tungsten carbide can be applied without difficulty and without the need for slow cooling.

An article on the properties and applications of Metco flame-sprayed refractory coatings appears elsewhere in this issue.

NEW CRUICKSHANK AGREEMENT

THE association of R. Cruickshank Ltd., Camden Street, Birmingham, with the Electro Chemical Engineering Co. for the supply of Efco-Udylite bright nickel plating solutions and brighteners has been discontinued, as reported in the July issue of this Journal.

Cruickshanks will, in future, supply "101" bright nickel plating solutions and brighteners by agreement with the Hanson Van Winkle-Munning Co. of America, and Dr. W. Kampschulte of Germany.

Their free installation and analysis service, backed by an augmented technical staff and research facilities, will operate throughout the country, and supplies and information will be available from their depots in Birmingham, London, Glasgow, Manchester and Sheffield.

Specifications for the solutions and brighteners are given in page 21.

INDUSTRIAL ART IN PAINT TINS

AT the beginning of last month, the Rt. Hon. Sir David Eccles, K.C.V.O., M.P., opened the new Packaging Centre in London. In the photograph below is seen one of the exhibits selected by the Society of Industrial Artists for display at the Centre; it shows Gay's new range of paint containers designed by David Caplan, F.S.I.A.

CHANGE OF NAME

THE name of A.D. Tack Rags and Adhesive Dusters Ltd., has now been changed to Anti-Dust Services Ltd., to indicate the wider activities of the company resulting from the considerable developments that have taken place since its formation.

The address of Anti-Dust Services Ltd. remains as before, at Stafford Street, Dudley, Worcs. (P.O. Box No. 28).

CHECKING MIX EFFICIENCY

A SERIES of tests using radio-active isotopes was carried out recently by the isotope division of the Atomic Energy Research Establishment, Harwell, at the works of Roto-Finish Ltd., Mark Road, Hemel Hempstead, Herts. Purpose of the tests was to determine the efficiency of mixing dry ingredients in a barrelling compound, believed to be the first time that isotopes have been used for this purpose.

The experiments were carried out with two production machines handling batches of 3 cwt. and 6 cwt. respectively. A third mixer was a prototype for which basic performance data had yet to be obtained. For the two large mixers it was required to test for uniformity of mix half hundredweight units filled into cardboard barrels ; some of these were tested further by taking four ounce samples from the top and bottom of the containers.

Although tests were not intended to be exhaustive, the results obtained provided a satisfactory picture of the uniformity of distribution of one of the ingredients, sodium carbonate, only 2 per cent by weight of the mixture.

Thus, in the 3 cwt. mixer, maximum deviation from the average reading (in counts per sec.) was approximately 10 per cent of the 2 per cent active ingredient present. For the large 6 cwt. mixer the maximum deviation from the average reading was less than 5 per cent of the 2 per cent active ingredient. In 4 oz. samples taken from the top and bottom of some of the barrels, the maximum deviation from the average was within 20 per cent of the 2 per cent active ingredient, showing that even with quite small samples the uniformity of mixing proved satisfactory.

The work was carried out by members of the A.E.R.E., working in close co-operation with Roto-Finish's Mr. H. P. Evans, Mr. V. Wood, and Mr. F. Mimpress. All instruments used, as well as the "activity" had been obtained from Harwell. The tests were made at the request of Dr. H. E. Zentler Gordon, metal finishing consultant.

PROTECTION OF PICKLING PLANT

Chemical Resistant Paints Stand Test of Time

CORROSIVE action by chemicals has always presented problems in industrial painting, and the high efficiency of today's chemical-resistant paints has only been achieved through long and intensive research. As a result of this research, many serious maintenance problems have now been overcome by collaboration between paint manufacturers and user.

An excellent example is provided by the treatment of Appleby-Frodingham Steel Co.'s pickling plant at their Scunthorpe works. Here, as in any pickling shop, the action of hydrochloric acid fumes and acidic condensation required serious consideration in the plant treatment of the building and cranes.

When the plant was first constructed chemical-resistant paints by Evode Ltd. of Stafford were selected, and these have proved effective over a period of nearly ten years. Painting of the steelwork and internal surfaces was begun towards the latter end of 1948. On steelwork, the specification comprised one coat of Evode protective paint primer (now known as Evo-led) followed by two coats of protective paint (now known as Evodyne) to selected shades.

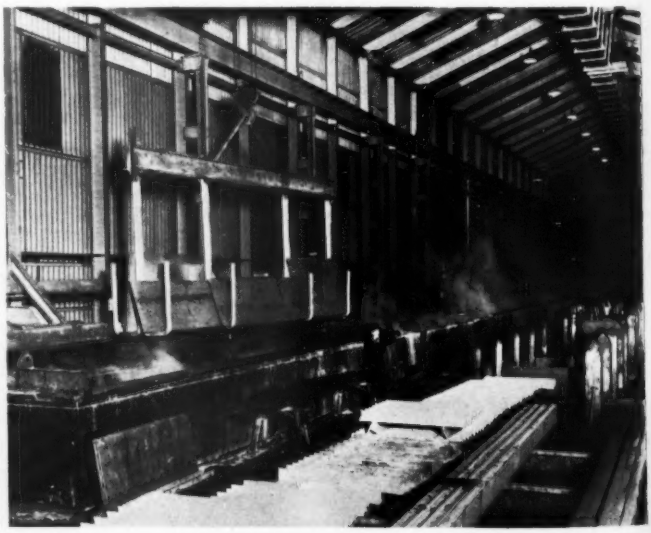
The asbestos sheeting received two coats of Evode protective paint to selected shades. The colour scheme (all steelwork and sheeting above crane track level — deep cream ; all below crane track level — turquoise blue ; crane girders — mid-buff ; and crane — sky blue and orange) conformed to Appleby-Frodingham's standard for such work; all shades selected and ordered were to B.S. 381C.

An extension to the pickling plant was constructed during 1950. The painting specification was similar to that used in the first instance, and the work was completed in the autumn of 1950.

Re-painting of the whole of the pickling plant, in line with Appleby-Frodingham's normal maintenance programme, became due during 1956. As the original paintwork was found still to be in good condition after 6-8 years' arduous service, thorough cleaning down and the application of only two coats of Evodyne C.R. paint, undercoat and finishing were considered adequate.

Spot priming of steelwork, where considered necessary, was carried out with Evo-led, but this was confined to those parts of the structure where excessive conditions were prevalent. A similar colour scheme to that adopted for the original work was used for the re-painting and this was completed two years ago.

The pickling plant at Appleby-Frodingham's Scunthorpe works.



Coated Sheet for Enamelling

Nitec Now In Commercial Production

THE new precoated steel sheet for vitreous enamelling announced recently by John Summers and Sons Ltd., of Shotton, Chester is now in commercial production (see METAL FINISHING JOURNAL, November, 1957, p. 433-455).

Known as Nitec, it consists of an enamelling grade sheet-steel base, produced in a basic open-hearth furnace and rolled by the continuous wide strip mill process. After annealing and cleaning, the sheet is subsequently coated with nickel and a protective coating of zinc.

Costing approximately £8 per ton more than ordinary vitreous enamelling sheet steel, the use of Nitec eliminates several stages in the vitreous enamelling process. Nitec need only be " pickled " for a period of three minutes, during which time the zinc coating will be removed and the steel degreased, saving many minutes in this operation.

The removal of the zinc coating exposes the nickel flash ready for enamelling. No further operations are necessary, and duration times for the processes can be reduced.

The makers also say that Nitec will give a more consistent finish than has been possible hitherto, and will reduce the number of rejects. They claim that adhesion will be better and more reliable and it will be possible to have a more consistent surface.

One development which is of great importance is in the single-coat finish, which obviates the necessity for a ground coat. Tests already carried out have shown that a " self-mottled " coat can be applied directly to the sheet.

For the small user, especially, Nitec will prove extremely economical, since it will reduce his operational times, and could lead to a reduction in direct labour charges.

The protective coating of zinc will have the advantage of preventing the rusting of the sheets during storage ; cleaning will be easier, and the sheets and semi-finished parts may be kept in store for some time without deterioration.

Nitec can be welded by all accepted methods, and welding conditions are not much different from those for uncoated mild steel. No special tooling is necessary for deep drawing; in fact the zinc in many cases assists deep-drawing operations.

BRANCH MOVES

THE address of their Midlands branch sales office of Borax Consolidated Ltd. is now Griffin House, 18/19 Ludgate Hill, Birmingham, 3. Telephone : Birmingham Central 2328.

Improved Grades of Refined Glycerine

THE United Kingdom Glycerine Producers' Assn., Ltd., Hesketh House, Portman Square, London, W.1, have announced the following changes in the refined grades of glycerine sold by its members.

The name of the grade previously sold as pale straw glycerine will in future be technical grade glycerine, and the specific gravity of both chemically pure and technical grade glycerine has been increased from 1.260 to 1.2627.

The new gravity will correspond to a glycerol strength of 99 per cent and no change in price will result from the introduction of the more concentrated material.

HEAD OFFICE ADDRESS

THE head office address of Armco Ltd., formerly 75, Grosvenor Street, W.1 is now 76, Grosvenor Street, London, W.1, where all postal communications should, in future, be directed. Telephone numbers, telegraphic and cable addresses remain as hitherto.

U.S.A.F. Contract for Borax Research

IT was announced recently that the U.S. Air Force has awarded a contract for the study of high temperature inorganic polymers and the chemistry of new solid rocket propellant components to the United States Borax Research Corpn., Anaheim, Ca. The corporation is the research subsidiary of U.S. Borax and Chemical Corpn., operating company in the United States for Borax (Holdings) Ltd.

The contract, which will be carried out in co-operation with the materials laboratory of the Wright Air Development Centre, is in support of research on inorganic polymers and plastics, resulting from the requirement for new materials that will withstand temperatures of 1,000°F. in missile and aircraft applications.

Present day polymers based on organic-carbon compounds are unstable at these high temperatures, but it is predicted from theory that inorganic materials containing little or no carbon will be thermally stable.

The exact nature of the inorganic polymer components to be investigated in connection with this contract has not been disclosed but it is expected that boron, nitrogen and aluminium will occupy an important place in the development programme.

A.D.A. ANNUAL GOLF TOURNAMENT

THE Aluminium Development Association recently held its thirteenth annual golf tournament at the Temple Golf Club, Hurley, Berks. A day of most enjoyable golf in unexpectedly fine weather was followed by dinner at the East Arms Hotel, when the hosts for the occasion were Imperial Chemical Industries Ltd., Metals Division.

As usual, the principal golfing event of the day was the Horace Clarke Cup Competition, won this year by Mr. J. D. King (The British Aluminium Co. Ltd.) with a score of 64. He was followed by Mr. W. A. Gardner (Aluminium Laboratories Ltd.) and Mr. E. H. Laithwaite (The British Aluminium Co. Ltd.) with scores of 71 and 72 respectively.

Winners of the foursomes competition were Mr. S. W. Almond (The British Aluminium Co. Ltd.) and Mr. W. J. Price (Birmingham Aluminium Casting Co. Ltd.).

At dinner, when a number of non-playing colleagues joined the competitors, the Horace Clarke Cup and the various prizes were presented by the president of the Association, Mr. S. E. Clotworthy (Northern Aluminium Co. Ltd.), who expressed appreciation on behalf of the guests for the hospitality of the day. Mr. F. B. H. Villiers made suitable response in the unavoidable absence of Dr. Maurice Cook.

CLEANING IN ONE PIECE

ULTRASONIC cleaning of complete jet engine assemblies — compressor rotors, turbine wheels, and combustion chamber nozzle assemblies — will be accomplished without stripping by " silent-sound " equipment to be built for the U.S. Navy by Alcar Instruments, Inc., Little Ferry, N.J., a subsidiary of The Narda Ultrasonics Corporation, Westbury, N.Y.

Alcar has received a contract from the Navy's Bureau of Aeronautics to design and build a prototype unit, with a transducerized cleaning tank approximately six ft. long, four ft. wide, and four ft. deep — making it one of the largest commercial ultrasonic cleaning units ever built. The ultra-high frequency vibrations that will remove loose dirt and baked-on combustion products will be produced by a multi-kilowatt generator.

It is expected that ultrasonics will cut down the time required to clean an engine assembly from twelve hours to under one hour.

U.S. Conference on Finishing

Detroit Meeting will Discuss Forty Papers

GOOD progress is being made in arranging the programme for the fifth international conference on electrodeposition and metal finishing to be held in Detroit, Michigan, from June 14-19, 1959. The educational programme is being formulated by the International Council, composed of appointed representatives of the Institute of Metal Finishing of England and the American Electroplaters Society of the United States. Approximately forty technical papers will be presented at the conference.

The subjects to be presented and discussed will include such matters as corrosion, process control and basis metal influence. Several papers will be presented covering the field of organic finishing. Methods of processing aluminium alloys are also included.

The International Council confidently expects that the various speakers will represent at least eight different countries of the world. According to advance planning, the five-day conference will probably include at least nine technical sessions, with an opportunity for its guests to attend an industrial finishing exposition. Plans for this phase of the overall programme are well advanced with many thousand square feet of floor space already arranged for by suppliers of equipment and processes.

The conference will feature the first William Blum lecture which is to be delivered by the first recipient of the new A.E.S. Scientific Achievement Award. Appropriately, the lecture will be delivered by Dr. Blum himself, a familar and highly respected scientist, who has spoken to audiences in widely separated areas of the world on subjects vital to the metal finishing industry.

ENAMELLED STEEL FOR CHIMNEYS

A COMPLETE range of vitreous-enamelled chimneys — claimed by the manufacturer to be the answer to condensation attack — is now being developed by Ferro Enamels Ltd., Wolverhampton, Staffs.

The chimneys are of the self-supporting type — from ground floor to roof level — and are made from enamelled steel, further protected by high-temperature building insulation wrapped around the steel liner; expansion joints are provided for variable temperature conditions.

The chimney stack can be matt-finished in any colour, or in a special enamel brick finish, and have welded flashing incorporated in the construction to facilitate easy installation to any roof angle. This company is also developing sectionalised chimney linings for use in existing brick-built chimneys.

METAL POWDER LABS. EXTENSION

A LABORATORY extension costing £15,000 is in the course of construction for the English Metal Powder Co., West Drayton, Mddx. Covering 2,800 sq. ft., it will be particularly concerned with giving research assistance to users of the company's products especially in the paint and lightweight concrete industry at home and overseas.

The range of equipment that is being installed will, however, broaden the scope of the laboratory to enable progress on many subjects relating to the use of aluminium powder and paste.

The laboratory will contain all the necessary equipment for the testing of aluminium stove enamels or any other resin based aluminium paint containing aluminium paste, and there will be a newly-designed gas reaction velocity measuring apparatus for the testing of aluminium powders for the lightweight concrete industry. The latter will be installed in a temperature controlled room. Further, a sea-water testing tank will provide facilities to study the influence of sea-water on aluminium paste based paints. This equipment will be especially valuable in connection with the development of marine paints.

Aluminium powder has many practical uses. In addition to the pyrotechnic, commercial and military explosive industries, quantities are consumed for silver printing and paper coating. Hundreds of tons of aluminium powder are sold by the company for the production of lightweight concrete. Other types of powder are used for metallizing plastics like P.V.C. and for various pharmaceutical preparations. Some types of aluminium powder made by the company are incorporated in cold solder, others in nail varnish and even in permanent waving pads.

CHEMICAL PROCESS DIVISION FORMED

THE formation of a chemical process division, with Dr. Bernard Schmidt as manager, was announced recently by Narda Ultrasonics Corpa., Mineola, L.I., N.Y. Dr. Schmidt is a graduate doctor in chemistry of the Technische Hochschule of the University of Berlin. His experience in Europe, India, Japan and other parts of the world on industrial applications of electrostatic equipment in chemical process fields makes a broad background for his approach to industrial application of ultrasonic equipment and techniques. British representative of Narda is Colonel J. D. Parker, Aveley Electric Ltd., Ayron Road, Aveley Industrial Estate, South Ockendon, Essex.

TECHNICAL *and* INDUSTRIAL APPOINTMENTS

Mr. Adrian Walmsley has been elected chairman of the north west branch of the **Institute of Metal Finishing** for the 1958/59 session.

Mr. Walmsley, who is 32 years of age, served his apprenticeship in the metallurgical laboratory, with emphasis on process control, at Rolls-Royce Ltd., Aero Engine Division, Barnoldswick. Subsequently he became assistant manager and later

Mr. Adrian Walmsley

manager of the plating department of Burco Ltd., Burnley, during a nine-year period of service.

He was appointed north western representative of Silvercrown Ltd., in August of last year. He had been lecturer in metal finishing at Burnley Municipal College for 4 years.

* * *

Dr. W. A. Baker, until recently research manager of the British Non-Ferrous Metals Research Association, has now left this appointment to join the **Northern Aluminium Co. Limited.** Beginning with the Association in 1935, he acquired an international reputation for his work on the casting of bronzes and of aluminium and magnesium alloys. He became senior metallurgist in 1946 and research manager in 1950. He is widely known in the metals industry for his broad metallurgical knowledge and practical outlook.

To fill the vacancy arising from his resignation, the Association has appointed Mr. A. Cibula and Mr. R. Eborall — respectively heads of the melting and casting and of the general metallurgy sections — as research superintendents, jointly responsible to the director for the work of the research department.

Mr. E. A. Bird, B.Sc. (Econ.) has been appointed export manager to the **English Metal Powder Co. Ltd.,** West Drayton, Mddx. Mr. Bird's appointment coincides with the opening by the company of a new plant brought into operation to meet an increasing demand for their aluminium pastes and powders. Aluminium pastes are principally used in the paint industry and for the manufacture of printing inks ; powders are used in pyrotechnics and the lightweight concrete industry. Over 75 per cent of the company's products are exported.

* * *

Dr. W. F. Coxon, M.Sc., F.R.I.C., F.I.M., M.Inst.F., is now practising under the name of **Co-ordinated Industrial Publicity** at 152, Fleet Street, E.C.4. (Telephone : Fleet Street 3521), and will specialise in all aspects of technical publicity.

* * *

Mr. L. F. Cooke, previously head of the industrial sales department of the **Cambridge Instrument Co. Ltd.,** 13, Grosvenor Place, London, S.W.1, has been appointed commercial sales manager. In addition, Mr. A. T. Jones, has been appointed sales manager of the mechanical thermometer division at Finchley.

WATERWORKS MEN VISIT FIRM

AT the beginning of last month, Wallace and Tiernan Ltd., Power Road, London, W.4, acted as host to sixty delegates from the south eastern area of the Association of Waterworks Officers. The visitors included Mr. D. W. Blackmore and Mr. B. T. Baldock, honorary general secretary of the Association, Mr. R. A. F. Lees, chairman of the south eastern area committee, and Mr. W. G. Close, a past president of the Association.

Wallace and Tiernan officials, including directors Mr. W. Dixon and Mr. B. Frisell, greeted their guests and made them feel at home before the address of welcome from Mr. W. H. Wood, the chairman and managing director.

The delegates were then conducted on a tour of the works covering the machine shop, test room, assembly, paint shop, packing and stores, and the research and development laboratories.

Among the fields of activity covered were dissolved oxygen recording, chlorine residual recording, dry chemical feeding, and cathodic protection of steelwork.

BREAKING UP ZINC SPILLS

ALTHOUGH modern heating and control techniques have minimized the dangers of local overheating in hot-dip galvanizing baths its occurrence is still not unknown and rupture of the bath wall due to accelerated zinc attack on the metal in the overheated area is often the consequence.

The escape of molten zinc from leaks thus caused can, if not rapidly detected, lead to quite substantial accumulations or " spills " of solid zinc. Owing to the ductility of zinc the breaking up of these large metallic masses often presents some difficulty.

One answer to the problem, however, is to freeze the spill with liquid nitrogen. This has the effect of rendering the metal brittle and it can then be broken up by means of a sledgehammer.

John Rigby and Sons Ltd., the Bradford wire manufacturers, sought the advice of British Oxygen Gases Ltd. recently when they were confronted with a spill weighing ten tons.

Liquid nitrogen was poured from a tanker on to the surface of the spill, gradually working from the outer surface to the centre. In this way, the mass of zinc was reduced to small sections with comparative ease.

When work of this nature is carried out in a confined space, precautions must be taken to ensure that operators do not inhale too much nitrogen gas. It must also be borne in mind that the surface of the zinc becomes extremely cold following the application of liquid nitrogen and can cause permanent damage if it is allowed to contact the skin.

This method of the reduction of scrap by extreme cold may well be applied in other industries to other normally ductile metals which have to be broken up.

Courses for Plating Industry

Series of Lectures at Borough Polytechnic

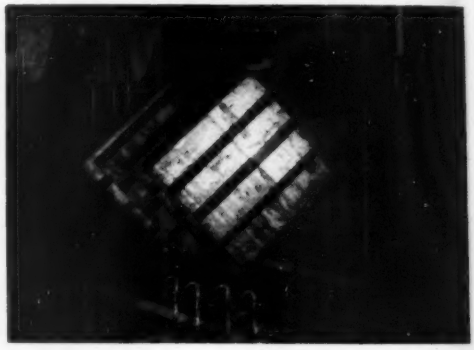
The department of chemistry and food technology of the Borough Polytechnic, Borough Road, London, S.E.1., are holding a series of eight lectures to be delivered on Wednesday evenings at 7 p.m., commencing on October 8, on recent developments in metal finishing.

The course is organised to provide a detailed and up-to-date survey of some selected methods of metal finishing and related topics. These will include not only lectures in technological topics, but also in human relations in the plating industry and in costing. Further details can be obtained from the Principal.

PNEUMATIC OPERATION OF GALVANIZING LINE

NEW building and construction developments, such as the gaining popularity of curtain walling employing zinc and aluminium coated steel sheets for exterior cladding of many types of buildings, are providing the metal window industry with a substantial new outlet for its products.

Integration of the new product into current production processes presents few problems, especially where galvanizing is concerned. Three methods are currently employed; namely, hot dip, zinc spray and electro-galvanizing. The hot dip process accounts for the treatment of a major portion of the output and although designed to handle large tonnages per shift, is sufficiently flexible to accommodate a variety of products other than metal windows without alteration to plant.



Right—A series of steel silo plates are being hauled between galvanizing stages by pneumatic rams, automatically controlled

Monorail System

At the Crittall Mfg. Co.'s Braintree works, the hot dip process is served by a monorail system, part of a works system. Small trolleys or carriers, from which hooks are suspended, are hand-hauled short distances along this system, loading being effected by lowering short sections of the rail complete with carrier and suspended hooks. Consolidated Pneumatic 6 in. dia. rams are used in the main shop for raising and lowering these sections, and a number of 4 in. units are installed in the paint department.

The hot dip process consists of pickling, two washing stages, fluxing, drying, galvanising, cooling and etching stages. The first stage, pickling, is carried out in a dilute solution of hot sulphuric acid, the temperature being controlled to between 140 and 150°F. After mill scale and other impurities have been removed, washing follows to eliminate iron salts, the first wash in a hot tank being followed by a cold wash. To ensure complete washing, the tanks are provided with a constant intake of fresh water and a waste overflow.

When all iron salts have been completely removed, a flux of zinc ammonium chloride is applied at a temperature of 150°F. This is effected in a further bath and its object when dry is to ensure an even flow of zinc in the galvanizing stage and to facilitate its alloying with the steel.

After fluxing, the next stage consists of drying in a carefully controlled air temperature. The removal of moisture is essential to prevent spattering in the galvanizing stage and close temperature control is necessary to prevent breakdown of the flux by interaction with the steel, with consequent heavy dross formation in the spelter bath.

From pickling to drying, the stages are carried out by a fully automatic circuit. After drying, however, the trolleys carrying the products to be galvanized are hand-hauled a short distance to the spelter bath, an arrangement which allows ample flexibility in the system.

A separate circuit controls the next group of stages. These commence with the galvanizing stage, carried out in a spelter bath kept at a temperature of 860°F. The surface is skimmed before immersion to remove zinc oxide and to prevent any possible contamination of the products; it is skimmed again before the windows or plates are withdrawn. A cooling stage follows and where frames or sheets are required to be painted they are treated by etching in a weak solution of phosphoric acid and zinc phosphate. This provides a roughened surface and a phosphate coating which has been found highly suitable for paint work.

Of prime importance in the process is a precise degree of control, whilst a measure of flexibility is necessary to deal with products other than standard.

The first of the two circuits is fully automatic, a timer being actuated by the fall of hoists controlling the vertical movement of the frames. When the timer makes contact, solenoid operated air valves supply air to the 4 in. dia. rams responsible for horizontal movement, the whole operation being contained by a series of integrated circuits incorporating "latch in" and "latch out" stages.

The Consolidated Pneumatic rams used for the carrier gear throughout the process operate in a highly corrosive atmosphere, being subject to acidic fumes from the tanks and to accumulation of corrosive material which tends to form on top of the cylinders. They are regularly inspected and maintained, however, and have been found to be ideally suitable to meet the conditions.

TECHNICAL BOOKSHELF

Anodised Aluminium *B.S.* 1615: 1958. London. British Standards Institution, 2, Park Street, London, W.1. 7s. 6d.

THIS British standard has now been brought up to date as a result of the work of a devoted committee, which is to be congratulated, and to whom the aluminium industry is considerably indebted for the painstaking work which its preparation has undoubtedly entailed.

It replaces the original standard published in 1949 and brings the methods of testing into line with current practice, while including some additional properties within its purview.

The scope of the standard covers the performance and testing of anodic coatings on aluminium and aluminium alloys produced by electrolytic means, but does not apply to thick, hard anodized coatings which have in recent years been produced specifically for wear resistance. It deals with the following properties in particular: surface finish; thickness; specular reflection factors (both white light and infra-red); abrasion resistance; colour; fastness to light; resistance to leaching; resistance to stains and electrical break-down voltage. This represents a comprehensive range of properties which should make it possible effectively to specify the majority of types of anodized aluminium coatings produced industrially, although the foreword makes it clear that it is not possible for any one coating to meet all requirements of this British standard, because individual requirements may prove to be incompatible.

It is evident that the committee has gone to very considerable trouble to specify the methods for the measurement of reflection factors. The abrasion test has also been revised in the light of difficulties experienced in its operation and the dimensions of the Test Jet are now more closely specified. In this connection the Bengough-Stuart chromic acid anodic film has not been found to be a suitable standard for comparison of coatings produced in sulphuric acid, and unfortunately, it has not been possible to find any other suitable standard specimen. Thus the test which is described in the standard is comparative only, and identical results may not be obtainable on different pieces of apparatus. However, work is continuing in order to improve the reproduceability of the test and users have been invited to communicate their experiences to the Institution.

It is thus evident that despite the considerable labour which has been entailed in the production of this standard, finality has by no means been reached. Nevertheless, the industry owes a considerable debt to those who have worked to produce the publication now issued.

S. WERNICK.

British Standards Institution Yearbook. London: 1958. British Standards Institution, 2, Park Street, London, W.1. 515 pp., 15s.

THIS yearbook contains information about the Institution and the services it offers. It lists the British Standards current at the 1st January, 1958, and gives a brief description of both.

Metal Industry Handbook and Directory, 1958. London. Iliffe and Sons Ltd., Dorset House, Stamford Street, London, S.E.1. 15s.

THE latest edition of this useful reference book has three main sections listed as: general properties of metals and alloys; general data and tables; electroplating and allied processes. A fourth section at the end of the book is a directory containing such information as trade names, associations and societies, technical institutions, a directory for buyers, etc.

FINISHING NEWS REVIEW

U.S. PLANT TO BE MADE IN U.K.

ALREADY well-known for their own polishing shop equipment and flexible shaft machines, the "Morrisflex" Group of Cos., under the leadership of the parent company, B. O. Morris Ltd., of Coventry, have concluded an arrangement with the Wallace Corpn. of America to manufacture under licence in this country Wallace tube benders and Wallace abrasive cut-off machines.

The machines enjoy a very high reputation in the U.S.A. and Morris are establishing a complete organisation here to manufacture and distribute these tools.

SERVICE AGREEMENT

THE introduction of a twelve months' maintenance agreement whereby a trained service engineer will visit customers' factories once every four months to overhaul and maintain Roto-Finish equipment was announced by this Hemel Hempstead company recently. The agreement will be available in the first instance to factories in the main industrial areas, but it is planned to extend the service to the whole of the U.K. in due course.

NICKEL EARNINGS DOWN

THE interim report of The International Nickel Company of Canada, Ltd., and subsidiaries for the three months ended March 31, 1958, was issued recently by Mr. John F. Thompson, chairman of the board of directors, and Mr. Henry S. Wingate, president. Net earnings in terms of United States currency are equivalent to 83 cents per common share, compared to $1.38 for the last quarter of 1957.

The report stated: "Deliveries of nickel in all forms for the first quarter were approximately 50,000,000 pounds compared with over 75,000,000 pounds for the fourth quarter of last year. The continuing lower level of demand and the size of our stocks of unsold nickel have required the company to make two successive curtailments of nickel production in Canada, reducing the annual rate of production as from May to approximately 250,000,000 pounds."

Completion of Inco's Thompson Mine in Manitoba is scheduled for 1960, with the first smelter production planned for July of that year. When completed, the plant will have a nickel production capacity of 75,000,000 pounds per year. Already a 30-mile railway spur connecting the mine to the Canadian National Railways' Hudson Bay Line has been constructed and the sinking of a development shaft of 1,057 ft. has been finished.

The production shaft is expected to be sunk to its full depth of 2,100 ft. by the autumn of this year. Erection of plants for the milling and smelting operations is well under way, and the foundation completed for a 500-ft. smelter stack.

TRADE and TECHNICAL PUBLICATIONS

U.K. WAGES ARBITRATORS

A NEW edition of the Directory of Employers' Associations, Trade Unions, Joint Organizations, etc., corrected up to January, 1958, has been compiled by the Ministry of Labour and National Service. Published recently by H.M. Stationery Office, price is 8s. net (by post, 8s. 7d.) from any S.O. bookshop or through any bookseller.

The Directory contains the title, and name and address of the secretary, of every organization in the United Kingdom of employers and workers directly concerned with the negotiation of wages and working conditions, or which provides representatives on bodies so concerned. In the case of trade unions an indication is given of those which are affiliated to the Trades Union Congress and the Scottish Trades Union Congress and of those which are registered under the Trade Union Acts.

NEW COMPANIES

"Ltd" is understood, also "Private Co."

Figures = Capital, Names = Directors, all unless otherwise indicated.

Kayburn Metal Finishing 79a, Westbury Avenue, London, N.22. June 16. £1,000. Stanley K. Conn, Henry B. Levy.

Scalemaster, 27, John Adam Street, London, W.C.2. June 17. £1,000. To carry on bus. of manufacturers of and dealers in filtering and purifying apparatus and plant and water treating and softening and scale preventing and removing plant materials ; manufacturing and retail chemists and druggists, etc. James R. Williams, Reginald W. Hodges.

Hard Chrome, 10, Bridge Street, Christchurch, Hants. June 20. £1,000. To carry on bus. of electro platers, etc. Rose M. Spink.

Ablow Industrial Plating, (Wolverhampton). July 4. £5,000. Reginald J. N. Davison and John N. Davison.

From the Register compiled by Jordan & Sons Ltd, 16, Chancery Lane, London, W.C.2.

Leaflet No. S91 entitled "Series 361 Recorders and Recording Control Stations" is now available from the Publicity Department, Electroflo Meters Co., Ltd., Abbey Road, Park Royal, London, N.W.10.

The recorder and control station has many new features—it occupies only 42 sq. in. of panel space and the makers say its 4-in. scale offers a greater scale length than many 12-in. circular chart recorders. Up to four measurements (two recordings and two indications) can be given with the recorder or control station and 22 models are available for different applications.

A 26-page catalogue (No. 65) **"Electrical Flow Meters"** is available from the same company. Details are given of the variety of differential pressure producers marketed by the company, including thin orifice plates, carrier ring orifice plates, flow nozzles, nozzle entrance venturi tubes, orifice flange assemblies and differential pressure measurements at fan inlets and in rectangular ducts. The electrical transducer flow meter converts differential pressure signals into electrical signals on a 40 V.A. circuit giving remote readings. The high-speed integrator may be fitted with a pick-up for data reduction and computing systems. Reference is also made to the new miniature 4 in./4 in. indicators, integrators and recorders, especially suitable for graphic panels. Useful notes are given upon the installation of differential pressure producers for different measurements, as well as information on open-channel meters employed in weirs and venturi flumes.

Many advances in paint technology over the last few years have increased the number of paint systems available. Each system has its own particular field of effectiveness and, confronted with this widening choice, architects, builders, maintenance engineers and painting contractors may well be excused some confusion in deciding upon which product to use for a certain job. Useful guidance on the correct choice of system for specific surfaces and conditions is contained in a collection of protective painting specifications recently issued by Tretol Ltd., Tretol House, The Hyde, London, N.W.9.

The specification sheets comprising the guide deal with the majority of corrosive conditions encountered in industrial premises. Additionally, several sheets are concerned with the painting and protection of various building surfaces and a section is included dealing with the selection of appropriate coatings for use in radio-active areas and which permit decontamination.

The publication is an easily-filed guide to modern anti-corrosive and specialised painting practice, and free copies are obtainable from the publications section of Tretol Ltd. Supplies are limited and requests should be made on business headings or accompanied by trade cards.

An outstanding feature of the April issue of **"The Nickel Bulletin"** is an extended abstract of a paper which will be regarded as a miniature handbook on the electroplating of nickel and its alloys : three tables contain much useful reference data. Reference is made in other abstracts to new electroless and electroplating processes.

The growing importance of powder metallurgy in industry is reflected by papers contributed to an international symposium on the subject, and by abstracts of literature relating to production and uses of sintered nickel-containing stainless steels and alloys. Other items dealing with heat- and corrosion-resisting materials include a paper on the machining of high-temperature alloys (recommendations relevant to nickel-base alloys are summarized in easy-reference form), recent specifications for nickel-containing materials, and papers listing some of the applications of corrosion-resisting materials in the chemical industries.

In constructional steels, an abstract of unusual interest summarizes information on methods of extracting and examining microconstituents in steels.

Other items in the Bulletin are concerned with investigations of the structure and physical properties of nickel and its alloys, and the issue also contains the first quarterly patent review of the year. Copies can be obtained from The Mond Nickel Co. Ltd., Thames House, London, S.W.1.

Poly. Man's D.Sc.

DR. Francis Aylward, head of the department of chemistry and food technology at the Borough Polytechnic, has been awarded the Degree of Doctor of Science by the University of Liverpool. (See *News*, page 322, "Courses for Plating Industry."

Latest Developments in PLANT, PROCESSES AND EQUIPMENT

Dry Blast Unit

THE new Autoflow dry blast units have been designed for the removal of plastic flashing, scale from castings, and rust from steel, to give matt finishes on components in metal, plastic and glass, etc. with small capital cost. (Fig. 1)

The units can be used with any of the known abrasives including steel shot, and the resultant finishes can be readily controlled. Single and double units are manufactured.

Air pressure of 80 lb. per sq. in. and an air consumption of 10—25 cu. ft. min. is required, depending on the size and number of guns used. The interior of the cabinets are zinc flame-sprayed to prevent corrosion and rubber-lined to give abrasion resistance. A noteable feature is a quick release valve to give simple and easy change of abrasive. An extractor of ample capacity is fitted to give clear and easy vision through the wide windows. Makers are Abrasive Developments, Ltd., High Street, Henley-in-Arden, Solihull, Warwicks.

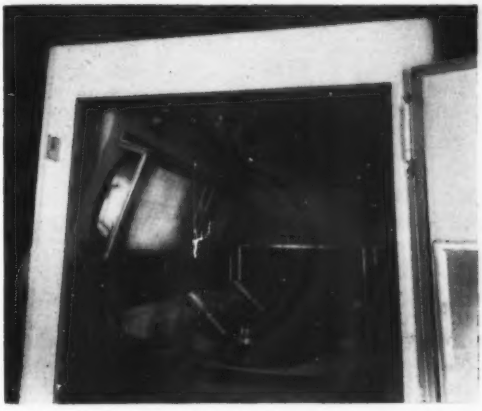


Fig. 1.—A feature of this dry blast equipment is a quick release valve to facilitate the change of abrasive.

Tack Rag Material used as a Doormat

THE A.D. tack rag material manufactured by A. D. Tack Rags and Adhesive Dusters Ltd. 53a Stafford Street, Dudley, Worcs., is now being used as an air filter over open windows, air ducts, etc., and in the ' Taccy Doormat ' for use in doorways into rooms where dust-free conditions must be maintained.

Sufficient experience with the white A. D. tack rag material as an air filter has been gained to demonstrate that it is very efficient, as well as being the means to construct at little expense, dust-free areas, the manufacturers claim.

The presence of dust in many industries often necessitates the installation of expensive plant and precautions are often wasted because dust is brought in on people's shoes. The Taccy doormat can provide the answer to this.

Electrolytic Conductivity Controller

THE type RC4 conductivity controller is intended primarily for permanent installation on processing plant, during the operation of which it is required to signal, or to effect corrective action, when the continuously monitored conductivity of an electrolyte reaches a predetermined value. The instrument may also be used to make periodic measurements to enable the state of the process at any time to be accurately appraised. The controller is connected to a measuring cell that is immersed in the electrolyte, or which forms a part of the pipeline carrying the electrolyte.

Electrical conduction takes place through a precisely known volume of the solution, the volume being determined by the dimensions and spacing of electrodes that are continually immersed in the solution within the measuring cell.

Small variations in the concentration of weak acids, or in the content of soluble inorganic impurities in water, produce substantial conductivity changes that are sensitively detected by the instrument and are thereby caused to actuate a relay which can be connected as required to operate visual or audible signals. For the purpose of automatic control, the relay can switch valves or pump motors related to the transfer of additives, or the admission or withdrawal of solution to or from the system.

The controller embodies a precision A.C. Wheatstone measuring bridge, unaffected by mains voltage variations and changes in electrical component values due to ageing, etc. The Wheatstone measuring bridge is supplied at low potential, at a frequency of 1,000 c.p.s., thus eliminating inaccuracies due to polarisation which would otherwise be present at low frequencies.

This equipment is fully described in a leaflet RC4 issued by the makers, Electronic Switchgear (London) Ltd., Works Road, Letchworth, Herts.

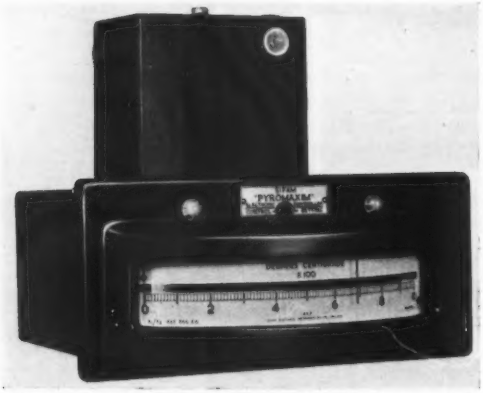


Fig. 2.—An electronic temperature recorder has an 8-in. mirror scale and an accuracy of better than 1 per cent. Automatic cold junction compensation is a standard provision.

Temperature Controller

THE Sifam Pyromaxim electronic temperature controller is now available from Sifam Electrical Instrument Co. Ltd., Leigh Court, Hr. Lincombe Road, Torquay. (Fig. 2)

A mirror scale of more than 8in. length ensures legibility and accurate reading of temperatures to better than 1 per cent. The calibration complies with B.S.S.1041 recommendations and the control response is within $\frac{1}{4}$ per cent.

The measuring galvanometer employs a powerful "Alcomax" magnet surrounding a moving system which swings between spring mounted sapphires. Automatic cold junction compensation is a standard provision. The movement and its pointer are completely free of mechanical stress or interference.

A simple electronic circuit provides the link between measurement and control which instantaneously operates an enclosed relay rated at 3 amp. and 250 V.A.C. non-inductive load.

A notable feature is the plug-in arrangement of the electronic amplifier unit which can be removed and replaced in a few minutes, thus facilitating installation and maintenance.

The "Pyromaxim" is available in ranges from 0-200°C to 0-1600°C or Fahrenheit equivalents. Calibration can be made for any type of thermocouple, a wide variety of which are made by Sifam. A new price list of the more generally used thermocouples is now available. Other accessories include compensating cable, gas valves, contactors, etc. The controller is supplied for either flush or wall-bracket mounting, for use with supply voltages of 110/220/240 A.C. The standard finishes are hammer grey or matt black stove enamel.

Factory Floor Overlay

A SYNTHETIC rubber coating, containing Goodyear's rubber resin "Pliolite", for use as a coating on factory floors, is being marketed in this country by W. David and Son Ltd., 47/9 Caledonian Road, London, N.1. Available in four colours—red, green, grey, and white—the coating is simply poured over the floor and spread with an ordinary household broom. A gallon is sufficient for two coatings on an area of 250 sq. ft. Resistant to many acids and alkalines, it can be applied to almost any type of flooring.

Addition to Range of Precision Measuring Instruments

A RECENT addition to the range of precision measuring instruments manufactured by the Micrometrical Manufacturing Co., 345, South Main Street, Ann Arbor, Michigan, U.S.A., is the "Vertical Wavometer" designed to increase the versatility of the standard "Wavometer" line, making it possible to measure surfaces of rotation up to 18 in. dia.

The "Wavometer" is an instrument for measuring waviness on symmetrical surfaces of rotation. The standard model unit will handle I.D.'s and O.D.'s of surfaces up to 18 in. dia., and provides for angular adjustments of 30 deg. above horizontal to 70 deg. below.

The "Wavometer" is simple to operate, requiring no technical knowledge or special skill. Specifically, it gives meter reading of the r.m.s. average height of the waves in two wave-bands, directly in microinches (millionths of an inch). In addition, an oscilloscope shows the general shape and spacing of the waves in either wave-band. A loudspeaker transforms the surface irregularities into sounds, and deviations from the normal are easily detected by the operator.

In operation, it performs three main functions: (1) It shows the effects of finishing processes on waviness. Lapping, polishing and similar operations usually reduce the surface roughness but commonly have little effect on existing waviness irregularities that were produced by machining or grinding.

(2) It shows what is accomplished by steps taken to obtain a less-wavy surface through changes in production operations.

(3) It provides for measuring work in the inspection and production departments, permitting unsatisfactory parts to be identified and set aside before they are finished or assembled, with resultant savings in time and trouble.

English agents of the company are Gaston E. Marbaix Ltd., Devonshire House, Vicarage Crescent, London, S.W.11.

Filter Equipment

SEDIMENTS of all kinds present in suspension in plating solutions must be continuously removed to avoid risk of contaminating the deposited metal coating. Such sediments or impurities can produce pitting or oxidation on the surface of the under-lying metal, and render the subsequent polishing particularly difficult. The continuous filtration of plating solutions has now become an accepted practice.

Grauer and Weil Ltd., Hardwick Street, London, E.C.1., have introduced two types of apparatus, having different filtering areas, and suitable for most of the tasks called for in a normal plating shop.

The two new filters are the " Dever " and the "Teddy " giving, say the makers, perfect retention of all the sediments and impurities present in the plating solution.

The Dever filter has a filtering surface of 17½ sq. ft. and a pump capacity of 2,000 gal. per hr., with maximum filter capacity of 1,750 gal. per hr. This is suitable for plating baths from 450 to 1,350 gallons, operating at a maximum temperature of 160°F.

The Teddy is similar in design to the Dever, but has a filtering surface of 8 sq. ft., a pump capacity of 2,000 gal. per hr., and a maximum filter capacity of 800 gal per hr. It is suitable for plating baths of 115 to 450 gal., working at a maximum temperature of 160°F.

They are robust, durable, easy to maintain, and entirely protected against corrosion, and the makers claim that in a recent test on a bright nickel bath of 875 gallons, operating for 24 hours a day, it was found necessary to clean the filter only once every 1,000 hours. No alteration is necessary to existing installations in the fitting of the equipment. Tanks over 1,350 gallons can be equipped with several of the filter units.

Plating Process for Printed Circuits

THE perfection of a new acid-type (*p*H 3.5 to 4.5) gold plating process, developed specifically for plating printed circuits, has been announced by the Sel-Rex Corpn., Nutley, N.J. U.S.A. The electrolyte is mildy acid so that neither the laminate nor the adhesive at the inter-face of printed circuit boards are affected during the plating process.

Among other advantages claimed for the process are: it operates at room temperature, obviating risk of damage to the printed circuit baseboards ; approximately 75 per cent greater resistance to abrasive-wear than conventional gold plate ; smooth, fine-grained, uniformly distributed bright gold plate regardless of thickness requirements; easy to prepare; and it is simple to maintain and control the solution.

Provided the copper base is properly cleaned the new process forms a firmly-bonded, fully adherent gold plate, the makers say.

A technical paper describing the new process, bath preparation and control, equipment needed and other topics of interest to printed circuit manufacturers, is available free of charge from the company.

Also recently announced by this firm is " CuSol ", a new acid copper plating process which is said to permit faster, smoother, more ductile deposits than any known method. It is described in a technical paper that has been prepared by the firm.

The CuSol process consists of two simple addition agents which may be used to " convert " existing sulphate fluoroborate copper plating baths, as well as to make-up original baths,

Among the advantages claimed for the process are : exceptional throwing power affording evenly-distributed deposits even in " blind " holes and crevices ; high ductility permitting the plate to be buffed as easily as gold ; elimination of uneven build-ups and " trees " ; there is no need for periodic reverse of " de-plating " methods ; the process is operable in a wide range of current densities—5 asf to 280 asf—permitting adjustment of the speed of deposition for specific requirements.

The process is expected to be of special interest to printed circuit manufacturers in that the process acid base will not affect the laminate boards, as do some cyanide-base solutions.

Agents in the U.K. for the Sel-Rex Corpn., are M.L. Alkan Ltd., Stonefield Way, South Ruislip, Mddx.

Small Electric Motor

KNOWN as the No. 7, a recently introduced " midget " electric motor is being marketed by Smiths Aircraft Instruments Ltd., Cricklewood, London, N.W.2. The motor, one of the smallest of its type in the world, measures 1.6 in. overall (40 mm.) and 0.625 in. o.d. (16 mm.). Robust and fully potted, the motor is built with non-corrodible laminations and is suitable for fitting to small servo systems, such as are used in guided weapons, where size is of principal importance.

It may be driven from a single phase 26 V. supply in conjuction with a 1.5 mf. tuning capacitor, or from a two-phase 400 c.p.s. supply. One available type can be operated directly from a pair of germanium transistors connected to the centre tapped control phase. Speed on no-load is 9,000 r.p.m. ; small torque is 8 grm/cm.

(*Continued in page* 328)

Plant Processes, etc.

(*Continued from page* 327)

Linings for Industrial Plant

HEXMETAL cellular reinforcement is now being widely adopted by heavy industry for providing "bone" in the protective linings and refractories of blast furnaces, dust collectors, and other industrial applications, say the makers, Causeway Reinforcement Ltd., 66, Victoria Street, London, S.W.1. Hexmetal is a fabrication of steel-walled honeycomb cells which, when loaded with cement or refractories, combines to provide a lining resistant to temperature variation, abrasion, vibration, corrosion and impact load.

The method employed is to affix headed studs at suitable centres on the plates for securing the reinforcement and to take the weight of the lining. The length of the studs is determined by the final thickness of lining required. The first layer of refractory is applied, up to the top of the studs, and the formed Hexmetal is welded to them. The final coat of refractory is then applied to fill the cells of the Hexmetal. This reinforced skin layer provides a surface of great strength.

Hexmetal may also be applied to the lower slopes of bunkers, dust collectors and the like. It is constructed with independent pin joints, the patented features of which were evolved to give flexibility without risk of broken joints under temperature variation, or when rolled to very small diameters.

[(*Continued in facing page*)

Classified Advertisements

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SITUATIONS VACANT

ALBRIGHT & WILSON (MFG) LIMITED, Chemical Manufacturers, require a qualified Chemist to operate a pilot scale electroplating plant. Other duties include visiting plating plants and advising users of the Company's products. This is a new post in an expanding field of work.

Applicants should be aged under 35 and possess a degree in Chemistry, though consideration will be given to men with electroplating experience.

The company operates a non-contributory life assurance and superannuation scheme, and also a house purchase scheme.

Applications should be addressed to Mr. F. B. Hunt (Ref. 481), Staff Officer, Messrs. Albright & Wilson (Mfg.) Ltd., P.O. Box 3, Oldbury, Nr. Birmingham.

Situations Vacant (*Cont.*)

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Plant Processes, etc.

(*Continued from page* 328)

Bright Nickel Solution

AS announced in this months *News* (page 317), R. Cruickshank Ltd., Camden Street, Birmingham 1, are now marketing a new bright nickel plating solution under an agreement with the Hanson-Van Winkle-Munning Co. of America and Dr. W. Kampschulte and Cie of Germany. The solution is marketed as " 101 " bright nickel plating solution, there being two main types available ; " M.101 " for use with mechanical cathode agitation, and " A.101 " for use with air agitation. There is also a modified form for use in barrel plating.

The basic solution is a Watts type, to which is added P.B. No. 1 and S.B. No. 2 brighteners. When used with mechanical agitation, an anti-pitting agent A.P.A. No. 3 is also added. The solution formula and operating conditions are as follows :—

Composition : nickel sulphate 40 oz./gal., sodium chloride (NaCl) 2.5 oz./gal., boric acid (H_3BO_3) 6.5 oz./gal., brightener P.B. No. 1 1.0-1.2 pints/100 gal., brightener S.B. No. 2 1.25 oz./gal., anti-pit agent No. 3 (mechanically agitated solutions) 1 lb./100 gal.

Operating Condition : temperature 110-140°F. to 130°F. optimum ; cathode current density 20-80 amps./sq. ft. 40 optimum ; anode current density 10-20 amp./sq. ft. ; electrometric pH value 3.5-4.5 ; agitation — vertical or horizontal (mechanical) (12.25 ft. per minute) or air agitation.

The brighteners are easily added to the solution the one being a liquid, and the other a readily soluble powder. The solution has a wide bright plating range and possesses excellent levelling properties, which ensure satisfactory results over a wide range of operating conditions.

The company says the deposits have exceptional ductility, combined with a high degree of levelling and brightness, and good receptivity to subsequent chromium plating.

Filtration of the solution can be carried out continuously through activated carbon, and this, together with the periodic addition of a small amount of hydrogen peroxide solution, maintains the condition of the solution over a long period, without the necessity of complete chemical purification.

Full analysis and plating control methods are given to all users, and a free installation and analysis service is maintained by the suppliers. Most bright nickel solutions in operation in this country today may be readily and economically converted and the suppliers will advise on the suitability for conversion of any existing solution.

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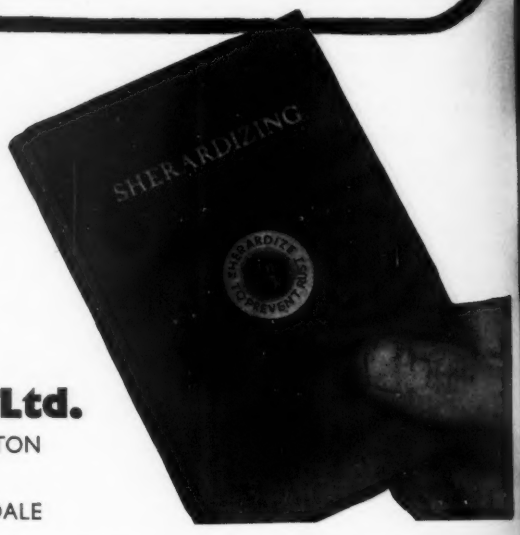

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